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IMPROVING SHIPBOARD DECISION MAKING IN THE CBR-D ENVIRONMENT: CONCEPTS OF USE FOR AND FUNCTIONAL DESCRIPTION OF A DECISION AID/TRAINING SYSTEM (DECAID)

to

U.S. NAVAL TRAINING SYSTEMS CENTER

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Chemical/Biological Radiological Defense (CBR-D) exercises at sea have shown critical shipboard tasks to be degraded when personnel function in such a CBR-D environment. It was recognized that decision makers need to extend their range of decision making skills, especially in the area of operational risk management. This document discusses the background, need assessment, task requirements, concepts of use, evaluation strategies, and a functional design description of a PC-based decision aid/training device (DECAID). The system focuses on Damage Control Assistants (DCA) as intial users. (Key words: Naval training, Performance (Human), [illegible], Computer programs, Threat, [illegible] vessels. (SDW) ✓

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A final note on authorship is offered. This report benefitted substantially from the contributions of all its authors. Consequently, the order of author names should not be interpreted to reflect their relative importance to this project. However, due to their project roles as principal investigator and naval consultant, respectively, the first and second authors bear responsibility for the treatment of topics covered in this report.

EXECUTIVE SUMMARY

PROBLEM

Chemical, Biological, and Radiological Defense (CBR-D) training has been deficient where it has been dealt with as an independent topic, not related to the overall tactical mission which may be taking place in the CBR environment. The CBR-D area is unique in that the defensive measures (i.e. closing up the ship and outfitting the crew in protective clothing) cause nearly as much mission degradation as would an attack itself. Shipboard decision makers need training to effectively weigh the risks associated with employing CBR defense measures, to make appropriate choices consistent with ship mission, and to plan operations in a CBR-D environment not as an "either...or" situation, but as "both...and", with CBR-D as an additional constraint overlaid on an ship's existing operational tasking.

OBJECTIVE

The objective of this effort is to provide concepts of use and a functional design description for a training device/decision aid (DECAID) that will provide a prospective Damage Control Assistant (DCA) with effective training in shipboard CBR-D decision making.

APPROACH

The approach has been to describe a desktop computer system which would emulate the displays, inputs, and information resources that would be available aboard ship. By means of scenario-driven situations, the DCA would be called upon to make decisions both of a simple, procedural nature and more complex decisions that require risk analysis to determine costs and benefits of the various possible decision options. A decision aid feature dubbed the "master chief" will alert the DCA to risk situations, forecast outcomes based on present conditions, and manage a resource library to assist the DCA in making decisions under conditions of uncertainty.

Several areas of utilization are described: 1. A classroom trainer suitable for use in the Navy's DCA curriculum. 2. A shipboard onboard training (OBT) package for incumbent DCA's to maintain or extend their skills in CBR-D decision making. 3. As a fully operational decision aid, compatible with a Damage Control Management System (DCMS), that would enhance a ship's capabilities to perform it's mission in a real-world CBR-D environment.

CONCLUSIONS

Development of a CBR-D decision aid/training device (DECAID) is feasible through an application of existing technologies. With only minor hardware upgrades it can be installed on the Navy standard (Zenith 248) desktop computer.

Providing DECAID for use in the DCA curriculum and aboard ship for use by incumbent DCA's will correct a longstanding deficiency in CBR-D training.

DECAID displays and communication protocols can be used as the basis for training in other areas of damage control decision making, and might be adapted for use as part of the DC central terminal for a future DCMS.

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SECTION 1.0

INTRODUCTION

Preliminary evaluation of recent Chemical, Biological, and Radiological Defense (CBR-D) exercises at sea (Carson, Moskal, and White, in press) indicates that several mission critical shipboard tasks would be degraded to the point that they severely impact the tactical situation. A CBR-D environment imposes stressors which can decrease crew performance and increase completion time for mission critical tasks. Operating in a CBR-D environment presents the tactical decision-maker with a unique situation in that assuming a defensive posture negatively impacts a ship's combat capability, almost as much as would an actual CBR attack. Furthermore, CBR-D may require entirely new methods (work-arounds) to complete certain shipboard tasks. This implies the need for naval personnel, from seaman to Battle Force Commander, to acquire the knowledge, skills, and procedural competence needed to perform effectively under conditions of CBR defense. One area in which this is particularly true is in the area of operational risk management. The complex decision making implied in CBR-D battle conditions requires a unique capability to synthesize and to generate effective combat strategies to assure mission success. Naval officers must be able to direct operations in CBR-D battle conditions in such a manner as to not only survive, but to prevail. To do so, an expanded range of decision-making skills and novel combat strategies are required. The urgency of this requirement is underscored by the fact that, unlike other aspects of naval operations, there are currently no "expert" officers who have experienced CBR-D battle conditions.

In response to the stated requirement for effective risk management training for CBR-D operations, the U.S. Naval Training Systems Center (NTSC) has requested that Battelle Columbus Division (BCD) develop a concept of use for a CBR-D Tactical Decision Aid (DECAID) Training System. The goals of this effort are to:

- investigate potential Navy applications of a desktop decision aid/training system (DECAID),
- develop a concept-of-use for one such application, and
- describe the high-level functional characteristics for this conceptual system.

Thus, this project is a concept formulation and feasibility study rather than a training system acquisition effort. Due to the 6.2 research orientation of this effort, the Instructional Systems Design (ISD) approach which is typically applied to training system acquisition is not fully appropriate to the present work. However, because many elements of the ISD approach are represented here, this document may serve as the foundation for a DECAID training system development effort if the concept of use, suitably refined by Fleet inputs, is judged to be of value to the Navy.

Originally, as described in the Statement of Work (SOW), this project involved four phases:

- Phase 1. Analyze the Navy's need for a CBR-D decision aid/training system and the conditions under which it might be developed.
- Phase 2. Analyze characteristics of the potential user community of such a system.
- Phase 3. Analyze task requirements involved in the initial application area the DECAID training system would address.
- Phase 4. Document the high-level functional specifications of the conceptual system.

In particular, a functional design document was proposed which would specify DECAID's high-level functional requirements, including generic hardware descriptions and conceptual instructional capabilities. This draft final report addresses the results obtained for each of the four phases of this project.

As is often the case in conceptual research, hypotheses held at the start of the project were later modified as a consequence of the data obtained. Data collection in the form of interviews with various Naval representatives, tours of various training facilities, and reviews of training and research documentation in the CBR-D area challenged many early hypotheses and introduced new ones. Changes to our original hypotheses and research focus are briefly discussed below.

We initially thought that DECAID would be best used for training Battle Force Commanders, Platform COs, or other senior officers to make tactical decisions in CBR mission situations. Instead, our work has led us to shift our attention to the Damage Control Assistant (DCA), a junior officer, who is the focal point for CBR-D aboard ship. The rationale behind focus on the DCA is contained in Section 2.5.1 of this report and it is, we believe, compelling. It is important to remember, however, that the DCA position is an initial, not only, application of DECAID technology; other fruitful applications may also be developed for the system at a later time.

We also originally envisioned that DECAID would provide instruction and/or aiding in the management of human (and time) resources in light of performance decrement resulting from the use of MOPP gear. CBR-D shipboard operations may be degraded due to heat stress, impaired communications capability, reduced dexterity, reduced sensory acuity, and so forth. Given that crewmen must work under encumbrances which can slow them down, reduce their effective duty time, and potentially increase errors, it is evident that officers must learn and use new decision strategies and thumb-rules which take performance time lags and loss of finesse into account. Over time, however, we determined that effective CBR-D decision making involves more than just management of human performance decrement. Such decision making involves high-order risk management; balancing implementation of performance decrement countermeasures against effective assessment of threat; and action selection appropriate to the criticality of the ship's mission. Moreover, much still needs to be learned about human performance under CBR-D conditions before a validated human performance advisory function may be practically implemented. Therefore, the scope of DECAID has been expanded to provide a more comprehensive coverage of decision aiding and risk management training necessary for effective CBR defense.

SECTION 2.0

DECAID NEED ASSESSMENT

BACKGROUND

Much of the material provided here is covered in the draft Statement of Need prepared for this project (Tijerina, 1987). Additional details are available in that source.

The Chemical Threat

Chemical weapons were first employed during World War I, where the trench warfare of Europe produced numerous gas casualties on both sides of the conflict. Afterwards, the 1925 Geneva Protocol limited the employment of chemical and biological weapons on the part of signatories to the treaty. It has been a model of effective arms control, in that chemical weapons have not been used in any major conflict since World War I.

Research and development have continued, however. The Chlorine and Mustard gases of 1917 have been supplemented with even more lethal agents, the most deadly of which are the nerve agents developed by Germany in the late 1930's, and further refined by U.S. and Soviet scientists after World War II. The latest technological development has been the binary agent, where two relatively harmless chemicals are combined during weapon delivery to form a toxic agent.

In recent years, the U.S. and Soviet Union have moved toward a treaty that would provide for the mutual elimination of chemical weapons from their arsenals. At the same time, there has been a proliferation of chemical weapon capabilities in other countries. Many of these are third world nations that support terrorist activities. Chemical weapons have been called "the poor man's atom bomb."

The risk of exposure to chemical weapons varies by ship class and mission. Ships operating far out to sea are at less risk than amphibious ships operating close to shore. All ships are vulnerable to chemical attack while transiting straits and choke points, and to terrorist attack while in port.

Chemical weapons, along with their biological and radiological counterparts, are unique in that they pose almost no physical threat to the ship itself. It is possible for hull structure, weapons systems, and electronics to survive in a CBR environment without any significant degradation. The threat is therefore exclusively a threat to the crew. From a damage control standpoint, the CBR-D task becomes one of increasing the survivability of the crew and minimizing the degradation caused by crew members having to perform critical tasks while wearing protective clothing. If conventional structural damage is complicated by CBR contamination resulting from a penetrating round, the damage control problem becomes very complex and demanding.

A unique aspect of the chemical threat is that the mere anticipation of an attack limits the ability of the ship to perform its mission. Forcing a ship's crew into gas masks and protective clothing for long periods of time has a degrading effect on morale, task performance, and sustainability of operations.

Chemical agents can be delivered in a variety of ways. Several common Soviet surface-to-surface missiles and air-to-surface missiles have been identified as having a chemical warhead capability. Projectiles common to field artillery and naval guns also can be filled with chemical agents. Warheads can be penetrating rounds that pass through the skin of the ship before exploding, or they can be air bursts that deposit chemicals on weather decks. Chemical agents can also be brought to the ship by personnel, boats, and aircraft returning from an amphibious landing or can be carried to the ship by an offshore breeze. Accidental contamination from weapons carried aboard ship is another possibility.

The Biological Threat

Biological warfare has been practiced in various forms for centuries. In earliest times, diseased animal carcasses were used to pollute enemy water supplies. During the French and Indian War, British forces intentionally created a smallpox epidemic among enemy Indian tribes by distributing blankets that had been used by patients in smallpox hospitals. Germany deployed a biological agent to incapacitate enemy cavalry horses during World War I, and there is evidence that Japan may have used biological agents in China during

World War II. The agents of biological warfare are essentially the agents of disease: bacteria, rickettsiae, viruses, fungi, and mycotoxins.

The threat of biological warfare agents to naval forces is ill-defined. Recent advances in microbiology have opened up infinite possibilities for creating lethal life forms through recombinant DNA technology. The Soviet Union has sophisticated laboratory facilities for biological warfare, and there have been incidents reported indicating that they may be actively pursuing research on lethal biological agents. How these agents might be delivered against a ship is not clear. Nor is it clear what unique defensive measures might be taken to protect a ship's crew against biological attack. Within the U.S. Navy, it is generally assumed that Biological and Chemical defense are linked, and that any measures that provide protection against a chemical agent would also be effective against a biological agent.

The Radiological Threat

Among the effects of nuclear weapons explosions are airblast, thermal radiation, electromagnetic pulse (EMP), radio blackout, sonar blueout, and initial radiation. In the context of CBR-D, the radiological threat refers only to residual radiation deposited on a ship due to base surge and fallout, and related delayed phenomena.

Radiation of sufficient magnitude causes personnel casualties due to the ionization and destruction of body tissues. A dose of 200 rad will cause personnel to feel nauseous but probably will not prevent them from performing their duties. A dose of 1000 rad is almost certainly fatal. The dosage is cumulative, so that exposure to residual radiation is added to the initial radiation exposure at the time of the nuclear explosion. Radiation is significantly attenuated by ship structure and seawater. Personnel whose battle stations are deep within the ship will receive a smaller dose of radiation than those personnel engaged in topside operations.

It is generally assumed that in wartime, ships at sea may be targeted with theater nuclear weapons, and that they may be authorized to retaliate in kind. Ships operating in a nuclear zone must be prepared to implement protective measures against residual contamination present in the zone.

Residual radiation is deposited on the ship through the combined effects of fallout, base surge, and radioactive pools. Fallout is a combination of the products of nuclear fission and seawater that was in the vicinity of the explosion, carried aloft in the characteristic mushroom cloud. Base surge is a mixture of radioactive mist and steam that proceeds along the surface of the ocean at great speed from the point of detonation. Base surge is of short duration, but fallout may continue for a period of several days. A radioactive pool is the result of an underwater explosion. It may cause contamination to adhere to the sides of the ship, and may be taken in through sea suctions.

Ships operating close to shore might experience fallout from a nuclear explosion ashore, which would consist of dirt and dust thrown aloft by the force of the explosion. Fallout from a nuclear explosion ashore would be more difficult to clean up than fallout composed of water soluble sea salts.

Recent Reassessments of the CB Threat

Chemical and biological (CB) warfare is morally repugnant to contemplate. Nevertheless, the Department of Defense in general and the U.S. Navy in particular must consider the potential threat of CB attack against our forces. In marshalling a defense against the possibility of a CB threat, it is necessary to first consider available evidence on the use or potential use of such weapons in recent years.

Consider first the Soviet threat. A report submitted to Congress in 1982 described evidence of the use of chemical weapons by the Soviets and their allies in Laos, Kampuchea, and Afghanistan since 1975. This evidence was based on interviews with former Soviet chemical warfare personnel as well as victims of chemical warfare, medical examinations of those victims, and analyses of material samples. From this it was concluded that chemical weaponry is being used on an ever-increasing scale, to the point that the possibility of chemical warfare can no longer be ignored. The Chemical Warfare Commission reached similar conclusions in a report published in 1985. Following are several salient points which were cited in the executive summary of the Commission's report:

1) The Soviet Union has pressed forward a major program to augment its capability to wage chemical war;

2) The Soviets have at least sixteen types of chemical munitions containing nerve agents and other chemical agents;

3) The Soviets have a large body of specially trained and equipped troops organized to assist units fighting in a chemically contaminated environment;

4) Evidence presented in the Commission's report suggests that the Soviets are actively developing new chemical agents, toxins, and bacterial agents as well;

5) The Soviet stock of militarily effective chemical munitions is estimated to be several times larger than that of the United States.

Second, consider the threat posed by third world countries. Recent reports on the use of chemical weapons in war are in reference to the Iran-Iraq conflict. Several visiting United Nations teams found Iraq guilty of using mustard and nerve gases against the Iranians. Recently, however, Iraq has agreed to let a United Nations team visit and investigate its claim that Iran has used chemical weapons against Iraq as well. It appears that at least one third-world country has developed CB offensive capability and has demonstrated a willingness to use it. Given the fanatical leadership exhibited by some third world countries and their hatred of the U.S., this threat category cannot be safely ignored.

Third, consider the threat posed by terrorists not affiliated with any recognized government. At the Second World Congress on New Compounds in Biological and Chemical Warfare, it was stated that a basic knowledge of chemistry and around $240 are sufficient to make 60 pounds of mustard gas, enough to threaten the population of a medium size city, let alone a naval vessel in port. The conclusion was that almost anyone could obtain large quantities of chemicals and convert them into weapons. The fact that chemical weapons are both cheap and easy to make increases the likelihood that they could be used by terrorists against both civilian and military targets. As was stated earlier, such weapons may aptly be referred to as "a poor man's atom bombs."

A final threat category not related to aggression involves accidents. Nuclear accidents are rare events but effective contingency measures must be developed and carried out in the event such accidents occur. Incidents such as the one that occurred at the Union Carbide Plant in Bhopal, India serve as grim reminders of the importance of disaster preparedness. Finally, it is important to remember that the threat of fires also often includes the threat of toxic fumes which threaten the safety of crewmembers. Many of the tasks involved in CBR defense apply to accident situations as well.

In order to provide a balanced view, it is necessary to indicate that controversy exists concerning the reliability of some of the evidence on the CBR threat. For example, reports released by Britain and Canada cast doubts on the claim that toxin weapons have been used by the Soviets and their allies in Southeast Asia. The supposed poisoning from chemical warfare agents can occur naturally from ingesting fungus-infested food. This does not mean that chemical warfare has not been waged, but rather that there may be a natural explanation for some of the findings. British work so far has failed to confirm reports of the presence of trichothecene mycotoxins in yellow rain samples collected in Laos and Kampuchea. Moreover, two recent studies conducted by the General Accounting Office (GAO) of all classified sources have uncovered no evidence of increased Soviet chemical capability.

The contradictory findings, absence of audit trails, and uncertainty over making an unequivocal judgment should not be taken as overwhelming evidence that there is no CB threat. It is not disputed that at least one third-world power possesses and has used CB weapons. It is not disputed that the Soviets do spend large amounts of money in preparing for chemical warfare. It is not disputed that terrorists could easily manufacture chemical weapons and use them against high-visibility targets. It is not disputed that accidents can create conditions similar to CBR warfare. Finally, lack of collaborative evidence on chemical agents in Southeast Asia should not blind one to credible evidence obtained in Afghanistan and other parts of the world. A major issue which must be faced still remains: What are the consequences even if an unlikely attack occurs and how prepared are the U.S. Naval forces to react effectively in such an event?

CURRENT NAVAL CBR-D READINESS AND TRAINING

The U.S. Navy is emerging from a period of complacency with regard to its capability to adequately defend against a chemical warfare threat. Through the late 1970's, very little consideration was given to chemical agent defense, in either ship design or individual protective clothing. Training was limited to a brief gas chamber experience for new recruits, and an occasional chemical defense drill conducted for ship repair lockers during refresher training. The only "advanced" training was a five day course in NBC (later called CBR) defense conducted at various Fleet Training Centers. Depth of knowledge was meager and personnel generally lacked the ability to effectively demonstrate self-survival techniques, much less the ability to perform their assigned jobs in a chemical environment.

Fortunately, the allied forces, particularly the British, had maintained an active program of shipboard CBR defense. The U.S. initiated a large scale procurement program to purchase British individual protective clothing. NAVSEA had also initiated a policy whereby all new-construction ship classes would be built with the Collective Protection System (CPS) concept.

The Chief of Naval Operations provided the impetus for improved CBR-D training with the promulgation of OPNAV Notice S3400 (30 September 1983). This classified directive called for various initiatives across the board to improve CBR-D readiness. One action called for the inclusion of CBR-D in tactical training courses. This was accomplished, but only to the extent permitted by limited time and resources. Thus, CBR-D implications are discussed in the classroom, but are not fully integrated into the tactical scenario and war-gaming aspects of training. Training for damage control personnel has seen more significant improvements, with the establishment of an advanced course for CBR-D instructors at Ft. McClellan, AL, and the implementation of a new two-day CBR-D course for all hands at Fleet Training Centers. The CBR-D portion of the DCA curriculum has been revised, and the training single-sited in a new building at Surface Warfare Office School (SWOS), Newport, RI.

NEED FOR CBR-D RISK MANAGEMENT TRAINING

Currently, the results of research on CBR-D related human performance decrement have not been presented to tactical commanders to guide them in establishing decision rules-of-thumb and policies that will allow them to effectively employ assigned forces under the additional burden of CBR-D. Given their lack of operational experience in a CBR-D environment, commanders need to experience the added complexity posed by CBR-D conditions to improve tactical decision-making training. DCA's as principal advisors to command in

CBR-D matters need experience making trade-off analyses and risk assessments appropriate to CBR tactical situations.

Consider the following example. Assume that in a training setting, hypothetical U.S. surface forces are assigned the mission of escorting third-party merchant vessels through the Persian Gulf to protect them from interference from either side in the Iran-Iraq war. Assume further that a chemical threat is possible, so that as a protective measure, MOPP Level II is prescribed for all personnel outside the citadel (if available). Given the already severe climatic conditions in the area, heat stress on exposed personnel will become a limiting factor as watch personnel need to be rotated more frequently. Perhaps more ships will be required, so that ships can be rotated in and out of the critical area. Ship commanders and tactical planners, as well as DCA's, need experience in dealing with these additional constraints so that real-world CBR-D decisions are not made in ignorance.

The need, then, is for tactical decision-makers, i.e., ship commanding officers, task group commanders, and their key staff advisors, to be exercised and experienced in CBR-D decision making. A training device could provide that exercise capability by presenting various tactical scenarios that require their action, but with the normal range of decision options constrained by CBR-D factors. As the students work through a scenario, the device could then display the consequences of those decisions or provide optimal decision recommendations. Through this iterative feedback, students could develop the higher order problem solving and decision making skills that are required for effective CBR-D risk management training. Ideally, this training would occur in the context of existing training courses, so that the constraints imposed by a particular MOPP level would be one factor among many to be considered by the decision maker. Alternatively, the device could provide 'part-task' training by focusing in on specific CBR-D operations (e.g., detection, setting MOPP levels, decontamination activities, contamination control activities).

Under CBR-D conditions, crewmen must work under encumbrances which slow them down, reduce their effective duty time, and potentially increase errors as well. Prevailing under these circumstances will require new decision strategies and gambits that take the lags and loss of finesse into account. The DECAID concept is intended to provide training in risk management that will help the decision maker make the best of a difficult situation.

THE CURRENT TRAINING SITUATION

Existing Training for CBR-D

TACTRAGRUPAC/LANT. The Tactical Training Group, Pacific Fleet trains senior officers who command multiple platforms, e.g., Battle Force Commanders and Task Force Commanders and their staffs. CBR-D instruction during their 2-week and 4-week commander's tactical training courses is limited to a 30-45 minute threat briefing. This briefing is often the first module to be eliminated from the curriculum in response to schedule slips. It is under consideration for elimination from the training program altogether, and thus is unlikely to be expanded in the foreseeable future. This is because CBR-D operations are perceived as unlikely to occur in most scenarios, and are given lowest priority in tactical training requirements. The Enhanced War Gaming System (ENWGS) does not currently include chemical warfare scenarios; however, Navy trainers think that building up such scenarios in the future could prove beneficial.

Personnel at TACTRAGRUPAC indicated that the Battle Force Commanders and other staff officers would issue general commands such as "Set appropriate MOPP levels." It would the responsibility of the individual platforms to implement this general command and advise the higher echelons of command as to the implications and consequences of carrying out the order as they have interpreted it. Thus, school representatives expressed the opinion that detailed CBR-D decision training would be inappropriate at this school.

Naval War College. The Naval War College (NWC) is responsible for training strategic planners. Most war gaming done at NWC is at too high a level to make use of detailed CBR-D operations; NWC training is even more removed from specified CBR-D events than TACTRAGRU training. Most NWC students are naval Commanders, Captains and their counterparts in other services (e.g., Colonels and Lieutenant Colonels.) In a representative war game, the lowest level participant may be in charge of five carriers and 50-80 escort ships. War College representatives did suggest that extending ENWAGS to include CBR-D overlays might be beneficial but indicated that CBR-D training via a DECAID system would be inappropriate because of its focus on specific shipboard functions.

SWOS. The Surface Warfare Officer's School (SWOS), Newport, RI, is the focal point for training surface fleet officers. Basic surface warfare officer's training is taught here as are ship CO, XO, and Department Head courses. For these students, CBR-D training is restricted primarily to a threat briefing and a review of new equipment which may reach the student's ships in the foreseeable future. Thus, it appears that ship COs and XOs do not currently receive in-depth training in CBR-D.

The Damage Control Assistant (DCA) course at the Surface Warfare Officer's School (SWOS) is currently the only Navy course of instruction that provides in-depth training in CBR-D operations and issues. At the present time, the DCA is the focal point for CBR-D on any ship in the surface fleet. The DCA would be looked upon to provide advisory support on the operational impact of MOPP levels (if such information were made available), direct CBR-D specific operations (e.g., decontamination and containment), as well as execute other damage control functions such as firefighting and flooding control. This is interesting in light of the fact that, with the exception of aircraft carriers, DCAs on surface ships tend to be junior officers. In fact, some 60 percent of the DCA students who receive DCA training have just graduated from SWOS basic and have never been to sea, much less had to consider managerial and decision making responsibilities. As the director of the SWOS damage control department indicated, the platform CO and XO will look to the DCA for technical advice on CBR-D plans and policies and for recommendations on alternative courses of action. Thus, it appears that the DCA is a good initial application for the DECAID concept of use study.

Ft. McClellan. In 1987, the Navy inaugurated a four-week CBR-D school for senior enlisted personnel, primarily of the damage control rating. The school emphasizes the chemical aspects of CBR-D and includes decontamination training in a laboratory with live nerve agents. The curriculum includes a section that in the future will integrate training received into a tactical scenario and will provide students experience with a sample battle problem; that portion of the course, however, has not yet been fully developed. Graduates of the course will serve on battle group staffs and as instructors.

They will perform an advisory role similar to that performed by DCA's and as such form a second potential application for DECAID training.

Shortfall Between Existing and Needed CBR-D Training

Currently, CBR-D training is not integrated into tactical training or war-gaming exercises. As a result of OPNAV Notice S3400 series, CBR-D is discussed during classroom portions of tactical training, but it is not a part of scenarios that are used in the "hands-on" portions of any training courses investigated for this project. While classroom discussion may be adequate for imparting declarative knowledge, the procedural skills needed to make in-the-loop decisions must be practiced in a hands-on manner to be adequately developed.

The same is true of at-sea training evolutions. Battle Force tactical training, conducted during the pre-deployment work-up cycle, has been programmed to include CBR-D, however, these training plans have never come to fruition because of the difficulty in integrating CBR-D decision requirements into the basic program. Integrating CBR-D is difficult because of lack of guidance, rules-of-thumb, and operational experience in a CBR-D environment. Coordination failures between damage control personnel and command and control specialists also contribute to these difficulties.

Most CBR-D research thus far has only served to identify hardware deficiencies and sorely needed ship design retrofits that are all very costly. Given present budgetary constraints, it is likely that current deficiencies will remain for the near term. What is really needed at this point is a system which will identify the "as is" state of CBR-D readiness, accept the limitations and constraints imposed by that state, then train tactical decision makers to incorporate those real-life CBR-D constraints into the range of naval contingency planning and operations. Current thinking is that in the event of a chemical attack, U.S. Naval units would leave the area. This may be impossible due to mission requirements, however. There is also the possibility that thickened chemical agents would "leave" right along with the ship. In addition, the area of contamination may be sufficiently broad, e.g., in a nuclear environment, that "leaving" may not be accomplished quickly. What is required, then, is a new mind-set on the part of tactical decision makers

Finally, DECAID could also be used aboard ship and ashore, both as a training device and as an actual decision aid, assisting the DCA or Disaster Preparedness Office to display the spread of contamination and to perform complex risk management analyses.

SECTION 3.0

ASSESSMENT OF USER CHARACTERISTICS

USER DEMOGRAPHICS: DCA STUDENTS

(Note: Information provided here are estimates provided by SWOS staff).

Age: Majority are age 22-28.

Rank. Estimates provided by SWOS faculty indicate that approximately eighty percent (80%) of the students attend DCA school at the end of their SWOS Basic pipeline. Thus, with rare exception, they are Ensigns. The remaining twenty percent (20%) are a mixed group of officers enroute to a DCA billet. Pay grade ranges from LT(jg) to Lieutenant Commander, with Warrant Officers, Limited Duty Officers, and an occasional senior enlisted student.

Shipboard Experience. As indicated above, 80% of DCA students have no shipboard experience prior to attending the SWOS DCA course. The other 20% of students have a range of fleet experience. Such experience may include, for instance, tours as a tactical action officer (TAO), Department Head, or Engineer.

Educational Level and Specialty. Virtually all students are college graduates with baccalaureate degrees. The majority of students have liberal arts degrees rather than degrees in science, mathematics, or engineering. The significance of this is high in that the DCA course is engineering oriented.

Familiarity With Computer Systems. Given their youth, it is highly likely that most DCA students have at least some familiarity with computer systems. This familiarity may be in any of the following forms:

- video arcade games,
- computer games,
- calculators (including programmables),
- word processors,
- spread sheets,
- computer-assisted instruction,
- use of data analysis packages,
- programming.

that includes CBR-D considerations in addition to a myriad of other factors that must considered in accomplishing the Navy's mission.

CANDIDATE DECAID APPLICATION AREAS

Initial Application: Training of DCAs

Training of the DCA was judged to be a logical initial application for developing the DECAID concept of use for several reasons. These are reviewed below.

Relevance to Fleet Operations. The DCA is the focal point for CBR-D on a surface ship. He is responsible not only for managing shipboard damage control in the event of chemical or biological attack but also for coordinating CBR-D specific operations such as detection, casualty control, and decontamination. The DCA is also looked upon as the primary resource person for CBR-D related matters by the platform CO and platform XO. The DCA is responsible for conducting on-board CBR-D training as well.

Relevance to Current Instruction. The DCA course at SWOS is the only course of instruction found during the trips taken on this project that provides time for a more in-depth treatment of CBR-D operations and issues. Specifically, the DCA course includes simulation exercises for decon equipment and a DECON trainer is slated for delivery to SWOS to enhance this aspect of training. The SWOS DC Central simulator could be enhanced by providing the instructor with DECAID performance decrement information for incorporation into more realistic simulation scenarios.

Potential Administrative Cooperation. It was repeatedly emphasized that executive support for any CBR-D program is a key element for its survival and success. The SWOS CO, at the time of this report, was highly supportive of computer systems for training and the incorporation of state-of-the-art technologies and information into SWOS courses. Furthermore, the SWOS DCA course is noteworthy in that SWOS, unlike most other naval schools, receives the latest equipment before the fleet does, not after the fleet does. Therefore, for the time being, it appears feasible to introduce the DECAID at SWOS with administrative support.

Perceived Need. The chairman of the DCA department emphasized the need for application of the theory and methods learned in the classroom setting. He sees the potential for DECAID, used in conjunction with the DC Central simulator, to increase the reality of the simulation experience and to improve student performance and application of all that the student has learned during the training program.

Feasibility. In addition to the reasons given above, the DCA emphasis is especially attractive because Battelle has a consultant on this project (John Stabb), who was a DCA on the carrier RANGER as recently as 1983, and provides subject matter expertise needed to flesh out the operational details for a DCA application of DECAID.

Other Potential DECAID Applications

DECAID training technology could be used elsewhere in the DCA course to provide training in scenarios involving fire and flooding with and without a CBR-D overlay. In the real world, multiple problems could very likely be the rule rather than the exception. Practice in integrating duties will provide the DCA with valuable experience which we anticipate will increase performance effectiveness aboard ship and heighten interest and motivation in the schoolhouse.

With modifications, DECAID could be used in the Ft. McClellan curriculum to provide senior enlisted CBR-D experts with training in shipboard decision-making. DECAID could also be modified for senior officers' tactical training, perhaps as a module within the Enhanced Naval Wargaming System (ENWGS).

The naval shore establishment could benefit from DECAID training for disaster preparedness officers at shore bases and for senior enlisted members who specialize in disaster preparedness. An application here would also be transferable to other military services.

The basic concepts and techniques of risk management training (see Section 4 of this report) could be applied to a broad range of warfare specialties, from the Tactical Action Officer aboard ship to the Gunfire Liaison Officer ashore.

DCA students can be expected to have some degree of computer literacy which may be developed further through interaction with DECAID and other automated naval systems.

Student Prerequisites and Qualifications. As indicated above, DCA students are graduates of the SWOS division officer course, during which they receive approximately 40 hours of damage control training, including CBR-D. Thus, they will be familiar with common naval terminology, basic command and control doctrine, and the organization of a ship.

USER DEMOGRAPHICS: DCA COURSE INSTRUCTORS

Damage Control Expertise. Instructors at the SWOS Damage Control School have extensive shipboard damage control experience, and will be able to evaluate the risk management aspects of DECAID training as well as the more straightforward procedural aspects. Their expertise should also be of benefit in the development of new DECAID problems, scenarios, and applications in the future.

Additional Training Requirements. It is anticipated that instructors will require orientation and training to familiarize them with the specifics of DECAID. In the detailed design phase of DECAID, every effort should be expended to minimize the level of computer proficiency needed to use and modify the system.

Familiarity with Computers. As time passes, it becomes increasingly probable that DCA course instructors will have had some exposure to computers. This exposure might result from college work, previous Navy training, experience with the Navy's SNAP II system aboard ship, or through work with other computer systems available at SWOS. Therefore, instructors can be expected to command appreciable computer literacy which may be further developed through interaction with DECAID.

SECTION 4.0

ANALYSIS OF DCA TASK REQUIREMENTS

INTRODUCTION

Much of an officer's job involves making decisions. In this decision making capacity, the officer must collect information, evaluate the information to arrive at a situational assessment, then develop and carry out a course of action. The skill with which an officer makes such decisions and directs human, materiel, and time resources defines his or her effectiveness. Therefore, operational effectiveness is enhanced when decision making effectiveness is enhanced. Decision aids and training should be oriented toward enhancing human decision processes.

Two classes of decision making may be usefully distinguished. First there are procedural decisions. These decisions are made regularly (i.e., they are repeatable) and are relatively well structured. An example is the DCA's assessment of the favorability of weather conditions for an enemy CW/BW attack. In such a problem the factors involved and their inter-relationships remain nearly the same every time the decision is required; only the specific values of these factors change. Because of their structure, procedural decisions are often handled well by standard operating procedures (SOPs) (Slovic, 1982). Therefore, it is appropriate that knowledge and policy guidance for procedural decision making be a part of an officer's decision training. Because they are well understood, procedural decision problems are included in most current DCA CBR-D training.

The second class of decision making involves risk management decisions. A DCA's decision on whether or not to leave a signal bridge crew without MOPP gear to control for heat stress despite the possibility of CW attack is an example. Risk management decisions involve the decision maker's assessment of the penalties and benefits associated with different courses of action, and of the probabilities associated with different outcomes. Decisions like this involve keeping risk within acceptable limits; such decisions are not normally addressed in current training because the "right answer" is not always apparent (Stabb and Herschler, 1987). Decisions can sometimes be benefitted substantially by decision aids. In addition, decision training may be directed toward the development of "educated intuition" and an awareness of one's subjective values and probability assessments. The ability to make risk management decisions is evaluated in the context of qualification boards (e.g., for command or Engineer Office of the Watch (EOOW)) but is not often evaluated in a training setting because the evaluation process is so dependent on the subjective judgment of board members, and is so manpower intensive. It often follows in the training community that what cannot be easily evaluated or tested is not taught.

Evaluating Risk Management Decisions

Intuitive decisions are sometimes poor because one or more biases creep in and degrade their quality. Sage (1981) and Wickens (1985) have listed a number of the common decision biases that people exhibit. Several of the more common biases, not necessarily independent of one another, are described below.

Anchoring. People tend to give undue emphasis to the early stimulus evidence in a sequence. This early data "anchors" one's perception and understanding of relevant hypotheses about the decision situation. The hypothesis suggested by the first data received has an advantage over other (possibly more relevant) hypotheses simply because it was established first. For example, the initial report of smoke in a compartment on the 03 level would lead a DCA to the hypothesis that there was a fire in that vicinity, even though the smoke could have been carried there by the ventilation system. The DCA's attention is "anchored" to that particular portion of the ship.

Availability. People tend to judge the likelihood of some event based on the ease (availability) with which similar events come to mind. Availability may be influenced by factors other than likelihood, however. For example, a recent (but otherwise unusual) event may seem to be "likely" simply because it is still on one's mind. If three trash can fires have occurred in B-division berthing during the previous week, a report of smoke in B-division berthing might lead the DCA to assume that it is from another trash can fire.

Conservatism. People tend not to revise their estimates in light of new information as much as they should. They underestimate the impact of highly diagnostic information and overestimate the value of less diagnostic information, tending toward a mid-range of estimates.

<u>Desire for Self-fulfilling Prophecies</u>. The decision maker may want a certain situation to hold and seek only information that supports the desired conclusion, ignoring contradictory data. Particularly if all fire party resources are already committed to investigating the two initial reports of smoke, the DCA might tend to defer action on new reports.

<u>Expectations</u>. People often remember and attach high validity to information which confirms previously held beliefs.

<u>Fact-value Confusion</u>. People may confuse strongly held values or opinions for facts. Data (facts) which contradict such values or opinions tend to be ignored. In the case of the USS Stark, the opinion that Iraqi warplanes would never fire on a U.S. Navy ship predominated over the facts presented on the radar scope, with disastrous consequences.

<u>Gambler's Fallacy</u>. The decision maker may falsely assume that a "run" of unlikely events increases the probability of such an event in the immediate future.

<u>Habit</u>. Familiarity with a rule for dealing with a particular situation may cause it to be applied to situations for which it is inappropriate. This is the "I have a hammer, therefore everything needs hammering" bias.

<u>Attribution of Successes/Failures</u>. People tend to associate success with personal ability and failure with chance; their critics may do the reverse. If fact, such attributions may not be justified.

<u>Redundancy</u>. The more redundancy there is in the data, the more confidence people tend to have in their decisions. Bias arises when the redundant data all comes from a subset of potential data, a subset which captures only a small part of the total picture. The DCA may trust the reports of six people who checked the same defective pressure gauge over the report of one scene leader who states that firemain pressure seems low.

<u>Illusion of Control</u>. A good outcome may have occurred by chance after a poor decision. If so, the decision maker may assume an unrealistic feeling of control over events. The opposite situation may also arise, i.e., frustration and misplaced feelings of helplessness may arise due to a chance failure in spite of otherwise excellent performance.

Representativeness. This refers to the extent that a set of data are similar to (or representative of) a particular hypothesis. If this similarity is present, then the hypothesis is selected over other hypotheses. Problems arise when the likelihood of the preferred hypothesis is much lower than another more likely hypothesis for which the set of data happens to be less representative. For example, there are similarities in the symptoms for heat stress and nerve agent poisoning. A DCA might evaluate a casualty report as heat stress because the symptoms seem to fit better, when the casualty is actually caused by a new variety of nerve agent.

Law of Small Numbers. People tend not to be sensitive to the quality of data and express greater confidence in a small set of confirmatory data than a larger set of disconfirming data.

Overconfidence. The greater the amount of data, the more confident people tend to be about its accuracy and the decisions they base on it.

Illusory Correlation. People tend to perceive correlations among data even when such correlation is absent.

Hindsight. Being told some event has occurred tends to increase our feeling that it was inevitable and that we "knew it all along." This can seriously prejudice the evaluations of decisions made in the past and limit our ability to learn from experience.

Elimination by Aspects. When faced with too many initial hypotheses or options to consider, the decision maker may focus only on one or a few critical attributes associated with them and eliminate all but the two or so hypotheses or options with the highest values for these attributes. Bias may enter in when attributes initially disregarded point very strongly to a hypothesis or option which has been eliminated from consideration. For example, the DCA of a large ship deciding which damage controlmen to send on a boarding and salvage party might focus only on primary damage control qualifications and ignore other attributes such as welding or foreign language abilities.

Data Saturation. Studies have indicated that, under time stress, decision making performance worsens when more rather than less information is provided. Despite this, the decision maker may often demand "all the facts" under such circumstances.

Outcome Irrelevant Learning. Use of a poor decision rule may lead to relatively poor results relative to other available courses of action. The decision maker, however, may think the poor decision rule is great simply because of an inability to evaluate the impact of choices not selected and hypotheses not tested. A DCA may inappropriately use the rule "If it ain't broke, don't fix it," and be satisfied with a temporarily sufficient solution rather than seeking an optimum one.

Numerical Estimates. People are fairly good at estimating averages (means), shy away from extremes on estimating proportions, and show substantial errors in estimating variability.

Training for Better Decision-Making and Risk Management

The items above provide an overview of how intuitive decision making may err. These biases arise because of limitations in how humans mentally process information. As a rule, humans exhibit the following limits:

- limited size and duration of short-term or working memory,
- unreliable recall from long-term memory (especially under psychological stress),
- difficulty in dividing attention across several tasks, and
- difficulty in mental calculations.

As an example, people seem not to be able to entertain more than three or four hypotheses at the same time. Decision biases persist because they reduce mental effort. Furthermore, they persist because they usually work well in day-to-day affairs! Thus, many of these biases may more appropriately be termed "heuristics" or rules-of-thumb. Heuristics are rules that usually work and reduce the time and mental resources needed to arrive at a decision. Biases arise when such rules-of-thumb prove inappropriate and induce decision making "tunnel vision." The challenge for training and decision aiding, therefore, is to

a) teach useful heuristics with a wide range of applicability,

b) increase the decision maker's sensitivity to conditions in which heuristics may not be appropriate, and

c) provide decision aids which help the decision maker to overcome cognitive limitations and to capitalize on cognitive strengths.

Decision training might take any of several forms. One approach is to help students develop associations between profiles of data, particular hypotheses, and actions. This approach capitalizes on the human desire to seek out relationships and to build associations. By building up in the student a "catalog" of data profiles paired to hypotheses and effective response strategies, the student's performance may be enhanced. Contingency training and training of SOPs is of this type.

Along with SOPs, students may be taught useful rules of thumb with wide applicability. This is potentially quite effective because a heuristic may be needed under certain constraining circumstances. Since it is difficult to teach SOPs which cover every contingency, rules of thumb may also be taught as means to modify SOPs to fit variations in the situation.

Another decision training approach is to make the decision maker aware of the nature of limitations and biases of which he or she may be totally unaware. This consciousness raising method might lead the decision maker to more carefully scrutinize his or her decision processes. There is evidence that this approach can reduce bias but cannot eliminate bias in all instances.

Yet another decision training approach to be considered is to provide comprehensive and immediate feedback in predictive and diagnostic tasks so that operators are forced to attend to how effective their decision processes are. Simulation might be appropriate for such an approach (Slovic, 1982). However, care must be taken that the simulation captures important aspects of the decision problem in order to maximize positive transfer of training. For unique decisions, a simulation with high transfer may be impossible to design because the real-life problem's structure is not well understood.

It is unfortunate that more is not known about decision training. However, a good start in decision training can be made using what _is_ known in the realms of routine decisions and in "consciousness raising" for unique decisions. Good decision making involves both knowledge about the decision problem(s) to be faced and procedures which make effective use of that knowledge. Initially, the DECAID training system may be oriented primarily toward training for procedural decision tasks. In this role, the focus will be on the knowledge needed to make such decisions and on procedures by which such knowledge may be used to arrive at effective command and control. Over time, it is envisioned that DECAID may increasingly be used to train for risk management decision making, where much research is still needed. DECAID might also be used as an information gathering device and research tool.

A final comment on training for risk management decisions should be mentioned at this point. Training usually must involve knowledge of results if it is to be beneficial. In the case of risk management decisions, however, the "right answer" cannot be known, i e., knowledge of results cannot be readily provided. However, even without knowledge of results, exposure to risk management decisions may be of value as a part of stress training. The notion here is that risk management decisions are stressful to make, but that prior exposure to such decisions may reduce their stress when they are encountered later in operational settings. The worth of this decision training concept merits further investigation.

COGNITIVE DECISION PROCESSES IN SHIPBOARD C^2

Psychology provides a general framework of human information which has been adapted to military command and control problems. This model is called the Stimulus - Hypothesis - Option - Response (SHOR) model (Wohl, 1981). An adaptation of the SHOR model to the DCA, developed for this project, is presented in Figure 1. The "Stimulus" element of the model corresponds to activities involved in assimilating the information needed for decision making. The "Hypothesis" and "Option" elements together comprise evaluating the information or processing it to arrive at an assessment of the situation and a suitable response option. Finally, the "Response" element refers to developing and executing command and control, i.e., articulating and carrying out a decision. This model reasonably represents what the DCA will be doing while engaged in CBR-D operations and damage control. Therefore, the SHOR model of the DCA represents the most basic and general "task analysis" appropriate for defining the tasks to be considered for training on DECAID.

Although human decision processes are highly interactive, this is not explicit in Figure 4-1. Specifically, damage control decision making is both data-driven and conceptually-driven. Data may be used inductively to <u>diagnose</u> the situation (i.e., arrive at one or more situational hypotheses). Once a

<table>
<tr><th>GENERIC ELEMENTS</th><th>FUNCTIONS REQUIRED</th><th colspan="2">INFORMATION PROCESSED</th></tr>
<tr><td rowspan="3">STIMULUS
(Data)

S</td><td>RECEIVE / DETECT</td><td colspan="2" rowspan="3">SOP s; Doctrine; CBR Bill;
Repair Locker Reports, Displays,
CO's Requests / Orders,
Intel, ...</td></tr>
<tr><td>FILTER / SEEK OUT</td></tr>
<tr><td>INTEGRATE / CORRELATE</td></tr>
<tr><td rowspan="3">HYPOTHESIS
(of situation)

H</td><td>CREATE</td><td rowspan="6">D
C
A

C
A
T
E
C
H
I
S
M</td><td rowspan="6"><u>DCA'S CATECHISM</u>
1. What is the status of my ship?
2. Where is the damage?
3. How is the damage progressing (progressive flooding, spreading fires, contaminant entering ventilation system?)
4. What are the most serious casualties that are likely to occur?
5. What are my personnel, equipment, and time resources to slow down the progressive damage?
6. How can I stop (repair) the damage?
7. Are any repair parties in position? Access / evac routes in order? Equipment accessible?
8. How long will it take my repair party to ... ?
9. How long before the damage does (this) .... ?
10. How will the damage look in 1 hour, as things currently stand? In 3 hours?
11. What is my number one priority?
12. What is my plan?</td></tr>
<tr><td>EVALUATE</td></tr>
<tr><td>SELECT</td></tr>
<tr><td rowspan="3">OPTION
(Response
Alternatives)

O</td><td>CREATE</td></tr>
<tr><td>EVALUATE with respect to TASK REQUIREMENTS</td></tr>
<tr><td>SELECT</td></tr>
<tr><td rowspan="3">RESPONSE
(Actions)

R</td><td>PLAN</td><td colspan="2" rowspan="3"><u>CREW TASKING</u>
Who   How
What   How Much
When   How Often
Where</td></tr>
<tr><td>ORGANIZE</td></tr>
<tr><td>EXECUTE</td></tr>
</table>

Figure 4-1. SHOR model of the DCA's decision processes.

particular hypothesis takes hold, however, the decision maker may use the concept to deductively guide data gathering, e.g., to predict what stimuli should be present if the hypothesis were correct. Similarly, hypotheses determine what options are relevant; these options may themselves require additional data collection for their evaluation and selection. Finally, the decision maker must receive feedback on the impact of his or her decisions in order to make further subsequent decisions. Therefore, the model of the DCA's decision processes should not be considered static; it actually represents a highly dynamic process, presented in static form to facilitate discussion. The distinctions among functions are not, therefore, clear-cut but are made chiefly to facilitate further work.

With this general model in hand, one may begin to prepare a generic set of instructional objectives to which decision training should be directed. These will be discussed according to the four elements of the SHOR model.

STIMULUS Element

The purpose of the STIMULUS element and associated functions is to obtain information about the situation(s) the DCA faces. Human errors in damage control decision making can come about because the decision maker "did not know" what the situation was, i.e., the decision was based on insufficient data. Therefore, it is of prime importance for decision training (and aiding) to address this part of the DCA's decision process.

The DCA can receive information from a variety of sources. These include repair party reports, changes on displays in DCC, orders from the bridge, notes in the ship's bills, as well as various sounds, sights, smells, the movement of the ship, and so forth. Decision training for this element can begin with high-level training objectives associated with each of the functions required in stimulus processing. These may then be used to derive concrete training objectives later.

Decision training objectives associated with the "Receive/Detect" function include:

> **Record and report data changes:** The DCA must learn how to interpret and record data received. This begins with an understanding of nomenclature and symbology and continues with an understanding of communications responsibilities (what to relay to the bridge, for example).

Encode uncertainty associated with unreliable data: Part of good decision making lies in realizing when information is not perfectly reliable and in factoring that realization into a decision. Estimating the reliability of a source and updating it in light of other data is therefore important. Intelligence officers, for example, must take data inputs which vary from hearsay to photo-reconnaissance and use them to arrive at an assessment of the threat.

Minimize missed data: The DCA should be trained/aided to avoid deciding no data is available when pertinent data is, in fact, to be had.

Minimize false alarms: Likewise, the DCA should be trained/aided to minimize the risk of deciding to seek data given that no data is actually available. Such an error of stimulus processing can be time consuming and tie up precious resources (e.g., sending a repair party out for a check when they are suddenly needed elsewhere).

Avoid data of low diagnosticity: Some data will not help damage assessment because it is either irrelevant or because it is equally likely under several competing situational assessments. Knowing what data sources are in this category, for various situations, should be part of decision training.

Objectives associated with the "Filter/Seek" function include the following:

Filter out extraneous data items: Not all information available can be (or should be) reviewed. The student must learn which data items bear most heavily on his decision tasks and which do not.

Seek missing data items: Training can help the student DCA identify what data are needed to reach a decision and where to get them.

Identify erroneous/unlikely data: Data may be in error for a variety of reasons and this must be identified in order to initiate a double-check and avoid introducing noise into the decision process. In a related vein, a data item may be sufficiently unlikely that it should cause a reassessment of the currently entertained hypothesis.

Time-sequence data gathering: Certain information (perhaps) must be gathered before other data can make sense. Other information may only be available after other information has been gathered. For example, a rate calculation will require that both numerator and denominator quantities are collected first.

Training objectives associated with the "Integrate/Correlate" function include the following:

> **Construct data profiles:** The student should be instructed in how individual data items may be grouped together into profiles or "syndromes" which suggest certain hypotheses.
>
> **Perceive higher-order relations:** Individual items which are evaluated together may provide additional information which no single piece of data can provide. The student must be instructed on how such higher-order relations may be derived.
>
> **Develop trends:** The DCA may predict changes in the situation over time by means of correlating data items and using these predictions in decision making.
>
> **Maximize use of partial information:** Earlier, the need to teach people how to synthesize higher-order relations from individual data items was mentioned. In other circumstances, collection of the right pieces of information may make additional data collection unnecessary. Expert decision makers can often work with limited data and "fill in the gaps" to arrive at decisions within the informational and time constraints the situation imposes upon them.
>
> **Integrating unreliable data over time:** Updating one's situation assessment (including uncertainty estimates) is also something which students may receive training/aiding to improve.

HYPOTHESIS Element

Data is useless unless meaning can be extracted from it. As was alluded to above, such meaning may be derived from either a bottom-up process or a top-down process which leads to the creation, evaluation, and selection of the hypothesis which most likely captures the state of the world. As Norman (1976) points out, both bottom-up and top-down processing must be carried out simultaneously in order to make sense of the world.

As a bottom-up, data-driven process, data serve as the building blocks for creating hypotheses about the tactical situation. In other words, the data are useful in diagnosing the state of the ship and arriving at one or more candidate hypotheses about the situation. In the case of multiple hypotheses, it is the case that humans can only entertain about three or four hypotheses at a given time (Wickens, 1985). These must be evaluated so that one or two of the most promising hypotheses can be used to predict data.

As a top-down, conceptually driven process, it is the hypotheses being considered which drive data gathering. A given hypothesis brings with it a set of expectations about types of data which are most relevant, the values these data should take on if the hypothesis is true, patterns among the data and so on. Such an approach to problem solving and decision making can be quite helpful, but its success depends upon the wisdom of what hypothesis to consider and what data to expect.

Training objectives for the "Create" function are as follows:

Associate situational hypotheses with data profiles: A significant part of decision training should focus on developing the associations between patterns of data, various situational hypotheses, and response options.

Prioritize hypotheses: DCAs should be taught about base rates associated with various types of situations and how to use these prior odds in rank-ordering various situational hypotheses. It turns out, for example, that physicians do not really take into account base rates for various diseases when making diagnoses, a bias which reduces their effectiveness.

Training objectives for the "Evaluate" function are given next:

Detect data contradictory to a current hypothesis: The DCA student should receive instruction on data which will discriminate between the current hypothesis and others which may be appropriate.

Detect absence of data as confirmatory for a hypothesis: People show a bias against the use of negative evidence, i.e., the absence of a symptom for diagnosing damage. This can be trained to some extent and may enhance the effectiveness of a DCA.

Optimally sample data sources: To evaluate competing situational hypotheses may require sound information sampling. Sampling too infrequently for data may cause the situation (and most relevant hypotheses) to change without the DCA's awareness. Sampling too frequently requires an opportunity cost (e.g. not being able to do another task) which may not be acceptable. Therefore, attention during training should be directed toward teaching the DCA an effective sampling strategy for a particular circumstance.

Prioritize data sought to evaluate hypotheses: The DCA must receive training on what data offer the most discrimination among competing situational hypotheses. The student should also receive instruction on tradeoffs among potential data sources, their associated costs, and their potential benefits.

Training objectives for the "Select" function identified thus far are primarily related to making the student decision maker aware of the limitations and biases alluded to previously.

OPTION Element

In the face of a particular situation, the decision maker will usually have more than one course of action open to him or her (Wohl, 1981). The decision maker may attack a problem directly or act to create more favorable circumstances for his forces, for example. In the face of two or more situations competing for attention simultaneously, option generation and/or selection becomes even more important. This function is where the decision maker must consider opportunities as well as constraints.

Training objectives for the "Create" function include the following:

Identify the goals to be attained: Once a situational hypothesis (or limited set of hypotheses) is settled upon, DCA must know what action goals are to be attained to bring about a more favorable situation.

Identify available courses of action (i.e., options): The DCA must receive training on strategies for meeting the identified goals to be attained. For example, if one goal is to extinguish a shipboard fire, the available courses of action might include use of different fire suppression systems. This will provide a set of options for further evaluation.

Training objectives for the "Evaluate" function should cover these points:

Assess option resource requirements: The DCA should learn to 'scope out' what the crew, time and equipment demands are for a contemplated course of action.

Identify conditions for and against an option. DCA training should also consider means for rank-ordering options even when all are within resource constraints. Some, for instance, may be quite robust in terms of still being "good enough" even in light of changes in the light of (modest) changes in the threat situation.

Evaluate the risk associated each option. The DCA should be trained to have some appreciation for the risk involved with the alternative plans of action being considered.

Prioritize short-term and long-term benefits: Under psychological stress, decision makers tend to emphasize short-term goals over long-term benefits. Training/aiding should be directed toward alerting the decision maker to potential disasters which might arise from such short-sightedness.

Predict outcomes associated with different options. Somewhat related to the previous objectives, the DCA will benefit from training which allows him or her to anticipate the results which a particular action plan is likely to entail.

Finally, one training objective for the "Select" function include:

Consider applicable doctrine. In selecting an option for action, it may be worthwhile for the DCA to review each optional plan of action with respect to naval doctrine taught during SWOS training.

RESPONSE Element

Without action, decision making has no meaning. Therefore, it is extremely important for student decision makers to be trained in the planning, organization, and execution of responses to situational threats. In the case of the DCA, responses will usually involve crew tasking in the following form:

Who - What repair parties/crewmen are needed;

What - What are they to address/fix/contain/decontaminate etc.;

When - What is the time window in effect;

Where - How do the crewmen get routed from where they are to where they need to be;

How - How will they carry out the course of action the DCA has judged as the most reasonable option;

How much - What equipment are required, what reserves are needed?

Decision training objectives for the Response portion of the decision process may include the following:

Master a repertoire of SOPs: The DCA should be trained to carry out standard operating procedures flawlessly. Overlearning of these may be a good way to avoid performance decrement due to stress.

Modify SOPs to fit variations in situations: See discussion under training on heuristics, Section 4.1.

Direct sufficient resources to carry out an action: A decision maker may know what to do (i.e., have chosen a sound option). However, he or she must also be instructed on how to carry the action out. Opportunities may be lost if insufficient human, time, or material resources are available to carry out a damage control action.

Direct only necessary resources to carry out an action: The DCA student must also receive instruction on deploying only essential resources to deal with a situation (provided such efficiency is required). Needless expenditure of effort or material may carry a serious penalty should that effort or material be needed elsewhere or at a later time and thus be unavailable.

Coordinate activities among repair parties: Should multiple repair parties be working on bringing the same situation under control, the DCA must be taught strategies to coordinate and synchronize their activities.

Communicate with CO/XO as required: The DCA must be instructed on reporting requirements and required permissions needed to carry out a course of action.

Take actions in optimum sequence: The DCA must prioritize action items and conserve resources to maximize efficiency and effectiveness.

DCA OPERATIONAL DUTIES AND TASKS

The SHOR Model of the DCA's decision processes provides a general analysis of the cognitive steps decision making entails. These steps will be carried out across the duties and task areas for which the DCA is responsible. It is the duty or task which provides the context in which the decision processes will be carried out, i.e., the specific data, hypotheses, selection rules, options, and so forth. Therefore, an analysis of the DCA's decision making requirements complements an analysis of the DCA's decision processes to support the development of effective decision training and aiding objectives.

A work breakdown of the DCA's job responsibilities, at the duty level, is provided in Figure 2; the CBR-D duty area is further broken out into various task areas. These may be used to categorize the various tasks which DECAID may address.

A task inventory of the DCA's CBR-D duties and tasks is provided in Tables 1 through 4. Analysis of critical tasks is required to develop instructional objectives suitable for DECAID. However, it is anticipated that CBR-D operations under battle conditions could realistically involve at least two other duty areas: 1) firefighting, and 2) stability and buoyancy. This relationship arises from the likelihood that CB attack may also be accompanied by structural damage to the ship resulting in fires and flooding along with the CB agent. DECAID offers opportunities to integrate CBR-D with firefighting

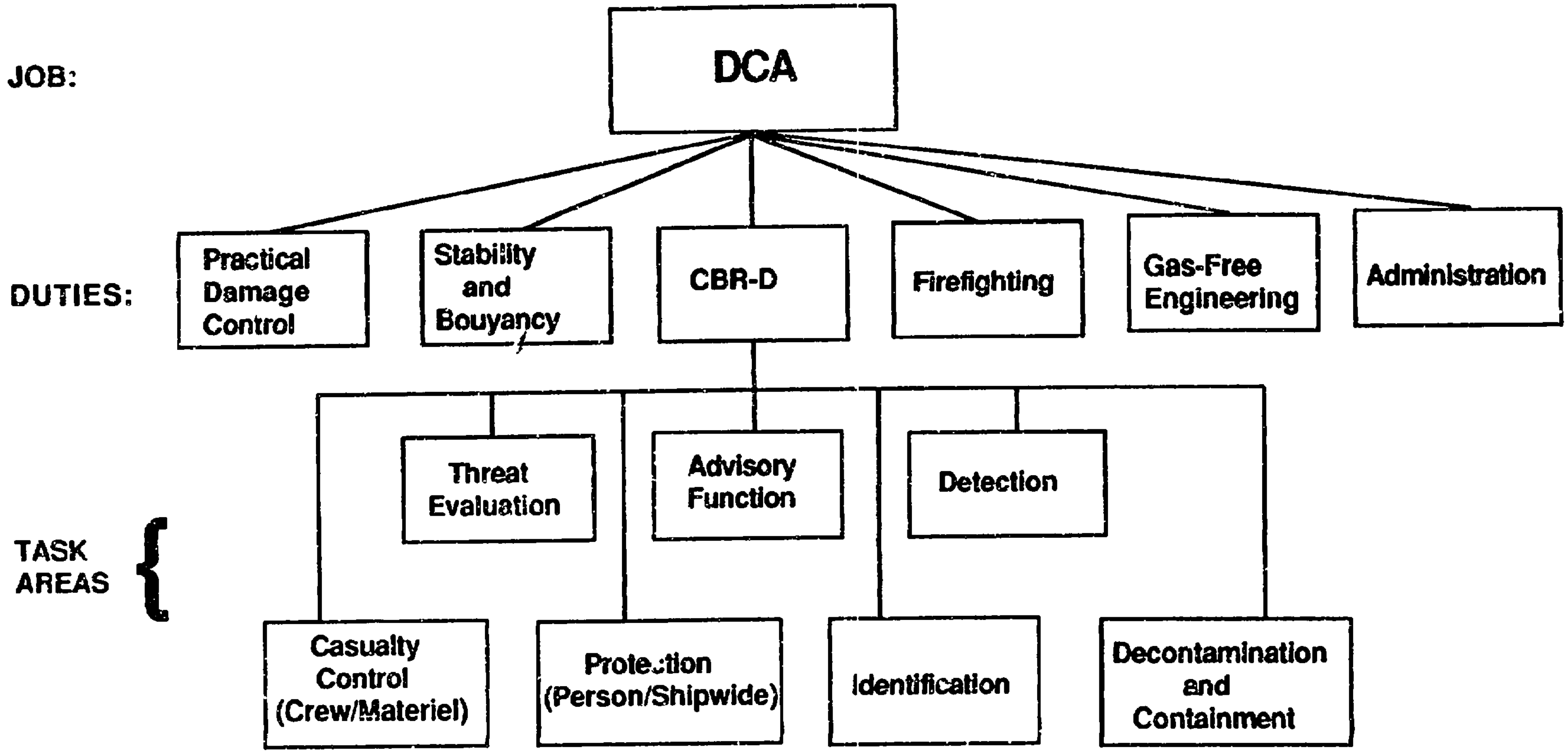

Figure 4-2. DCA work breakdown structure.

and stability duties, thus providing the student DCA with opportunities to develop decision making skills in a more realistic context than might be available if CBR-D is treated in isolation.

Table 4-1

Chemical/Biological Warfare Duties and Tasks

A. Operating in Vicinity of Known or Suspected BW/CW Threat

1. Recommend Condition Zebra for all doors leading to weather decks
2. Conduct operational inspection of personnel decontamination stations
3. Breakout and issue M-258/258A1 personnel decontamination kits
4. Inspect chemical and biological sampling kits to ensure completeness
5. Conduct operational inspection of washdown system
6. Post M-8/9 detector paper throughout ship

B. BW/CW Attack Probable

1. Recommend Circle William
2. Recommend intermittent activation of washdown system
3. Activate all personnel decontamination stations
4. Dress out internal traffic controller
5. Dress out and equip all essential topside personnel
6. Direct repair lockers to stand by to transmit internal chemical sampling data to DCC, and biological samples to Medical Department
7. Recommend MOPP level to CO
8. Establish watch station rotation and MOPP level
9. Estimate CBR-D equipment usage
10. Determine heat stress factors and risk
11. Respond to requests for routes
12. Determine whether weather conditions are favorable for an attack

C. BW/CW Attack Imminent

1. Recommend Circle William
2. Recommend continuous activation of washdown system
3. Recommend MOPP level to CO
4. Estimate CBR-D equipment usage
5. Respond to requests for routes

D. BW/CW Attack Occurs

1. Order repair lockers to conduct internal sampling survey using M-256 chemical detector kits and biological kits
2. Determine extent of contamination
3. Advise bridge of current and predicted BW/CW hazards based on all available information
4. Establish routes for casualties
5. Establish routes for decontamination teams
6. Investigate for structural damage

Table 4-1 (Continued)

E. Operational Recovery Phase

1. Recommend continued activation of washdown system for 15 minutes
2. Order repair lockers to conduct detailed sampling of external areas using M-256 chemical detector kit and biological sampling kit
3. Continue internal survey until there is no longer an indication of internal contamination
4. When external decontamination has been completed, retest and report to predesignated area
5. Announce location of the casualty collection station
6. Inform bridge when ship is clear of all known contamination
7. Inventory Individual Protective Equipment (IPE), detector paper, etc. to determine extent of shortages

Table 4-2

DCA - Nuclear Warfare Duties and Tasks

A. Nuclear Attack Probable

1. Order warm up and test of radiacs
2. Breakout and issue dosimeters and DT-60S
3. Recommend intermittent activation of washdown system
4. Recommend Circle William
5. Recommend MOPP level to CO
6. Evaluate weather conditions
7. Respond to routing requests
8. Position area monitoring dosimeters

B. Nuclear Attack Imminent

1. Recommend continuous activation of washdown system
2. Recommend Circle William
3. Designate personnel decon and casualty collection stations
4. Recommend that nonessential topside personnel take deep or ready shelter
5. Recommend MOPP level for topside personnel
6. Respond to routing requests

C. Nuclear Attack Occurs

1. Investigate for structural damage
2. Assign designated personnel to deep shelter
3. Dress out all essential topside personnel
4. Approximate topside and below-deck radiation intensities
5. Commence on-station radiological monitoring
6. Advise bridge of fallout arrival, peak intensity, and cessation
7. Keep bridge informed of dose/rotation times for bridge personnel
8. Recommend rotation of personnel
9. Initiate rapid internal survey
10. Initiate rapid external survey
11. Recommend that countermeasure washdown system be activated
12. Calculate safe stay times for external survey and decon teams
13. Oversee selective decon of vital stations or general decon
14. Oversee detailed survey and decontamination
15. Cordon off hot spots that can't be cleared of radiation
16. Establish routes for casualties and replacement personnel
17. Activate personnel decon station
18. Designate casualty (dead) collection station
19. Redesignate decon/casualty collection stations if necessary

Table 4-3

DCA - Firefighting Duties and Tasks

A. Prevention of Fire or Smoke

1. Direct the stowage, protection, and elimination of combustibles
2. Inspect and ship spares
3. Educate shipboard personnel in fire prevention
4. Enforce shipboard fire protection policies

B. Detection and Identification of Fire or Smoke

1. Establish ship-wide reporting system
2. Identify location and type of fire and/or smoke--establish nature of fire

C. Plan for Firefighting and Smoke Control

1. Alert appropriate fire party
2. Determine optimal technique for fighting fire and controlling smoke
3. Determine equipment to be used
4. Set fire boundaries
5. Plan alignment of fire main
6. Request approvals for shutdown of electrical equipment
7. Call for general quarters

D. Plan for Personnel and Material Protection and Casualty Control

1. Determine potential combustible within fire boundaries and plans for removal or protection
2. Determine isolation procedures of personnel, material and equipment
3. Determine "closures" and ventilation
4. Prepare evacuation plans
5. Alert medical/first aid personnel

E. Direct Firefighting and Smoke Control Activities

1. Inform seniors in chain of command of firefighting and smoke control status
2. Specify plan of attack to fire party leader
3. Specify fire boundaries, evacuation plan, closure, ventilation control, and protection of personnel, materials, and equipment to fire party leader
4. Maintain communication with fire party leader
5. Receive reports on fire and smoke status from fire party leader
6. Coordinate with other repair parties

F. Investigation and Assessment of Fire and Smoke Damage

Table 4-3 (Continued)

1. Direct examination, examine areas within and adjacent to fire boundaries

2. Determine damage and casualties

3. Direct assessment or assembly repair needs
4. Inform senior in chain of command of results of investigation and assessment
5. Prepare reports

G. Direct Cleanup Activities

1. Direct dewatering and desmoking
2. Direct removal of debris

Table 4-4

DCA - Stability and Buoyancy Duties and Tasks

A. Detect Instability and Nonbuoyancy

1. Establish reportir system
2. Monitor gauges an instruments
3. Receive reports ot instability and nonbuoyancy

B. Identify Cause of Instability and Nonbuoyancy

1. Receive report of cause for instability and nonbuoyancy
2. Examine damaged area on flooded area to determine cause and extent of damaged/flooded area

C. Plan for Stabilizing and Buoying Ship

1. Alert repair party(ies)
   Call for general quarters
2. Determine strategy and technique for restability and changing buoyancy to the ship--counter flooding, ballasting, deballasting, solid weight shift, jettisoning, flooding control, plugging, patching and shoring
3. Request command approval for ballasting, deballasting, counter flooding and jettisoning
4. Determine equipment and material to be used
5. Set flood boundaries
6. Determine need for stranding ship

D. Plan for Protecting Personnel, Material, Equipment and Casualties

1. Determine personnel, material, and equipment safety measures
2. Inform personnel of instability and/or nonbuoyancy, and degree thereof, and safety measures

E. Direct Stabilization and Buoyancy Activities

1. Specify plan to protect personnel, material and equipment to repair party leader
   Specify flood boundaries to repair party leader
2. Specify plans to stabilize and change buoyancy of ship to repair parties leader and other personnel
3. Maintain communication with repair party leader
4. Receive reports on stabilization and buoyancy of ship
5. Coordinate with other departments/divisions in maintaining stability and buoyancy
6. Prepare list of topical material which can be jettisoned
7. Direct personnel in jettison activities

Table 4-4 (Continued)

F. Monitor Results of Stabilization and Buoyancy Activities

1. Monitor and maintain stability status board (flooding effects diagram)
   -- Location of flood boundaries
   -- Effect of list and trim
   -- Effect of corrective actions
2. Monitor and maintain Liquid Load Status Board (fuel and water tanks)
3. Inform supervisor, seniors, command of ship stability, buoyancy, list, trim, watertight integrity
4. Receive and evaluate information from all repair party leaders
5. Investigate and assess flooding and causes of instability or nonbuoyancy

SECTION 5
DECAID CONCEPTS OF USE: INSTRUCTIONAL DELIVERY

INTRODUCTION

One concept of use for DECAID is for instructional delivery. Currently, much of SWOS DCA instruction is provided through a lecture format supplemented with printed instructional materials. In addition, the DCA course is augmented by demonstrations, films, and hands-on exercises with equipment (e.g., exercises in the DC Central mock-up). As SWOS training evolves and incorporates concepts and systems such as DECAID, it may prove worthwhile to reconsider current instructional delivery and evaluate whether or not computer-based instruction might not be worthwhile for delivering at least a portion of the course content.

Instructional delivery through DECAID offers several benefits to both the staff and students of SWOS. It can free staff up to provide (more) individual tutoring to students, to concentrate on those aspects of the course which can really benefit by an infusion of instructor shipboard experiences, and to incorporate a seminar format for discussion of decision making, risk management issues, and other topics of interest. In addition, computer-based instruction could streamline or eliminate some of the time-consuming clerical duties of teaching (such as grading).

Instructional delivery through DECAID likewise offers several benefits for the student. Specifically, instructional modules administered by DECAID offer the following benefits:

- immediate feedback on performance
- training tailored to individual abilities (e.g., remediation, review, or advanced training for more advanced students)
- a feasible means of providing high-quality instruction in CBR-D, damage control, and decision making at sea for on-board training (OBT).

Computer-based instructional delivery through DECAID may have certain disadvantages. As Eberts and Brock (1987) have pointed out, a major disadvantage of computer-based training is the length of time needed to author one hour of instruction; they present a table in which the ratio of development hours/hour of instruction is as high as 2286 and as low as 6.9. There are also limitations in the communication modes available between student and computer, these usually being limited to keyboard, touch panel, or mouse. Yet another disadvantage is that computer-based training software normally cannot handle unexpected or unique answers well. Finally, computer-based training works best for delivery of facts and is (currently) less suitable for areas (e.g., decision making procedures) where the knowledge to be learned is less explicit. These disadvantages must, of course, be weighed against the potential advantages which might accrue from including instructional delivery in DECAID's functional capability. However, we believe that there are many opportunities to provide instructional delivery via DECAID in such a fashion that it will benefit all DECAID users. These are discussed below.

CANDIDATE TOPICS FOR DECAID INSTRUCTIONAL DELIVERY

Decision making can be thought of as a form of problem solving. It is therefore pertinent that research in cognitive psychology and artificial intelligence has led to the conclusion that, in order to solve complex problems, one needs facts/procedures and also methods for manipulating those facts to arrive at a solution (cf. Rich, 1983; Winston, 1984). Facts provide the context within which problem solving (including decision making) may be carried out. From this assessment, one can surmise that useful instructional modules could be designed to address factual aspects of damage control (in general) and CBR-D (in particular) which are currently a part of the SWOS curriculum. Some of these areas, and other topics for inclusion in instructional modules, are suggested here.

<u>SWOS DCA Course Topics</u>. A number of topics in the current SWOS DCA curriculum could be addressed in DECAID instructional modules. A brief listing is provided below (topic titles are ours):

RAD CALC:	Module(s) to teach the performance of radiological calculations.
CHEM AGENTS:	Module(s) to instruct on the defense against chemical agents. Note that similar modules could be developed for biological agents as well.
DECON:	Modules which cover topics in CBR-D monitoring and decontamination.

STAB CALC: Module(s) which address principles of stability, methods of stability calculation, ship design implications for stability, etc.

COUNTERFLOOD: Module(s) which address dewatering, counterflooding, ballasting, deballasting, solid weight shifts, and jettisoning.

Similar concepts can be thought of for other portions of DCA coursework. It appears, then, that at least some of the material which is part of the current DCA curriculum might be suitable for DECAID instructional delivery. Inputs from SWOS faculty will, of course, be necessary to determine what modules might be most beneficial.

General Problem-solving Methods. A variety of general approaches to problem-solving might also be presented via DECAID instructional modules. The training objective would be to augment instruction on facts and SOPs with strategies the DCA might employ for solving problems of CBR defense and damage control. The aim of this instruction would be to increase the range of approaches with which the DCA may "attack" his decision problems. These general methods do not work by themselves but, when augmented by relevant facts and experience, they can be quite powerful for solving complex problems such as those involved in shipboard decision making.

Problem solving methods have been studied extensively by researchers in artificial intelligence (Rich, 1983; Winston, 1984). They are important to AI because they form a core component of useful AI/expert systems. A few such methods which might eventually find their way into DECAID instruction are given below:

Generate-and-test: In this approach, the problem solver a) generates a possible solution, b) tests to see if it works, and c) either quits if the solution worked or else generates another possible solution and goes through the process once more.

Means-Ends analysis: This process centers around differences between the current state (e.g., fire in a compartment) and the goal state (fire out, desmoking completed, power reestablished). Procedures are then selected with respect to their ability to reduce the observed difference between the current state and the goal state.

Breadth-first

search: In searching for the most plausible situational hypothesis, for example, this approach suggests one consider each incoming data item against all hypotheses until the bulk of evidence clearly favors one hypothesis over the others. This is distinguished from depth-first search in which the hypothesis suggested by initial data leads to a focus on that hypothesis to the exclusion of others.

Backchaining: With this strategy, one reasons from goal state to present state in order to identify intermediate states which must hold; this these one can develop a plan of action. For instance, the goal state (e.g., fire in a compartment out, desmoking completed) has a precondition state (e.g., desmoking completed), which itself must be preceded by a precondition state (e.g., fire out), which must also be preceded by other states, until one comes to the present state (e.g., report of a fire in a compartment).

Forward reasoning: This strategy is the reverse of the one just presented, i.e., one reasons from the present state to goal state.

Instructional treatment of these methods (and others) would presumably include a translation of them into DCA contexts, a discussion of their advantages and disadvantages, and perhaps some exercises both in determining when to use particular methods and how to implement a chosen method.

In addition, to the artificial intelligence concepts just given, DCA students might benefit from exposure to other available problem solving approaches as well. The mathematician G. Polya, for example, has witten a classic book on problem solving which, while oriented toward mathematical problems, contains many potentially useful hints for solving practical problems (Polya, 1957). Stated as a series of thought-provoking questions, Polya's approach is given in Table 5-1; it has been augmented by tentative 'interpretations' in terms to which the DCA can relate. (Note the similarity between it and the DCA's Catechism presented in Section 4 of this report). Again, instruction on such ways of thinking may prove valuable in a decision training environment and should therefore be considered further.

Training to Use Decision Aids. As will be discussed in a later section, any decision aids contained within DECAID have training implications in and of themselves. At a minimum, the user must be instructed in the syntax of the

Table 5-1

Polya's General Problem Solving Strategy With Possible DCA Applications

Stage of Problem-Solving	Questions-Approach	DCA-related questions
Understanding the problem	What is the unknown?	What's the damage?
	What's the condition?	What goals apply, what resources are available, and what constraints are imposed? Is it possible to save the ship?
	What are the data?	What are the damage reports, symptoms, equipment readings, etc. telling me? Am I using all the data available? Do I have time, men, equipment to get more data?
Devising a plan	Do you know a related problem?	Have I seen this in DCA course, DECAID, heard about it in the fleet, experienced a similar damage threat before?
	Can you break the problem down?	Can I restate what I am facing, what must be done to isolate, contain, extinguish, reconfigure, repair?
Carry out plan	Can you see that each step in the plan is correct?	Can I check the correctness and completeness of this plan with respect to doctrine, bills, training, current state, etc.? Can I check the argument which led to this plan, e.g., change the order of reasoning steps?
Look at results	Can you check the result?	Can I use this result another time? What must be modified on the next iteration of damage control (if applicable)?

aid, i.e., how to enter data and commands, request and control displayed output, sequence from one transaction to the next, correct errors, and so forth. It has also been suggested that users also be introduced to concepts of decision theory such as probabilities, rationality, statistical inference, subjective utilities and the like (Nickerson and Feehrer, 1975). Evidence suggests that this is beneficial for an informed and enlightened use of decision theory and decision aids as a whole. It is also worthwhile noting that such training is needed, for example, in using statistical models as decision aids so that the DCA can comprehend the displayed output; such displays would presumably employ confidence bands, prediction intervals, cumulative probability functions, etc.

Other types of instruction to support sound use of DECAID decision aids may also be indicated. For instance it is important that the user of a decision aid understand both the content-area principles (e.g., stability and bouyancy, human performance prediction) and appreciate the limitations of models and data bases which are used for decision aiding. Such instruction will be helpful in allowing the user to appreciate assumptions or defaults built into the aid, boundary conditions beyond which the aid should be used with caution, as well as value-laden aspects of a decision aid (e.g., 'risky' expert systems).

APPROACHES TO DECAID INSTRUCTIONAL DELIVERY

The approaches which might be used within DECAID instructional modules are varied. It seems that whatever approach is used, instruction should adequately treat, to the extent possible, concepts, methods, and applications. First, concepts include the theory and principles behind what is being addressed in DECAID instruction; treatment of concepts addresses "what" is the topic being instructed. This is judged to be important because psychological research into decision making has suggested that, if training on concepts supports causal reasoning, then that can improve diagnostic reasoning, probability assessments, and judgements (cf. Levi and Pryor, 1987). For example, in instruction on radiological calculations, it is important that the student understand fallout phenomena and key terms. Second, it is also necessary to train the student in methods appropriate to the decision task. Continuing on the previous example, a DCA must learn how to construct a log-log plot of a radiological situation, how to use appropriate nomographs, how to make predictive calculations, and so forth. Third, DECAID instruction should follow through to cover applications. Using the radiological calculations example once more, it is not enough to teach the student how to derive time of arrival (Ta), time of peak intensity (Tp), time of cessation (Tc), decay rate (n), and so on. The application of these values comes in making decisions about safe stay time for crew members, so this should also be a part of the instruction material.

Assuming that one knows what should be taught, how might instruction be achieved? It is well beyond the scope of this report to provide an extensive review of approaches to instruction. We will, though, briefly mention a few approaches which appear to have relevance to DECAID concepts of use for instructional delivery.

The "learning loop".

Traditionally, "learning" has been thought of as process that involves an instructor, a classroom and a textbook. Learning is viewed as somewhat passive. Concepts are gained from books and instructors and are (perhaps) to be thought about and (perhaps) to be applied at some future time.

The U.S. Navy has been in the forefront of efforts to make training a "hands on" process, not only in technical training, but in the fields of problem solving, decision making, and leadership training. War gaming has been conducted at the Naval War College since the turn of the century. Experiential group dynamics training concepts were developed under a Navy contract after World War II. In recent years, scores of sophisticated training devices have been developed to provide realistic operational training ashore, in a variety of specialized areas.

Behind this effort to provide hands-on training is the notion that learning is not merely a passive activity, but to be fully effective must include some active application to reinforce what has been taught in the classroom. The concept of the "learning loop" illustrates the principle. In this concept, there are four elements to the learning process:

1. Concrete Experience. The active participation in an actual or realistic training evolution.

2. Reflective Observation. Thinking over what happened during the evolution. Evaluating the results.

3. Abstract Conceptualization. Developing high-order generalizations about the experience. Developing ideas for further testing.

4. Active Experimentation. Trying out the implications of the concept or generalization in a new but related evolution.

In an effective training process, the learner cycles through each element of the learning loop, testing out new concepts in a concrete experience. Each element of the learning loop provides necessary input to the next (see Figure 5-1).

In such a process, the student must take an active role in learning. It is important that the student honestly reflect on the concrete experience and integrate the resultant "lessons learned" and apply them in new situations. It is not appropriate for the student to be totally dependent on the instructor to point out "what should have been learned" in the exercise. The Navy student needs to take responsibility for his/her own learning and develop the skills that will carry over beyond the classroom environment and provide the capability for continued learning in the shipboard operational setting.

In the area of CBR-D decision making, DECAID will provide the opportunity to move beyond the classroom discussion of hypothetical situations. It will provide students with some realistic concrete experiences upon which to apply their conceptual learning, and from which new lessons may be drawn. Thus, the "learning loop" approach has relevance for both instructional delivery and for scenario presentation (See Section 6).

Discovery learning. The discovery method is an effective teaching strategy for problem solving, in which the learner is "guided" to discover for himself or herself the higher-order rules needed for problem solving. It does not imply that problem solving can be achieved with a minimum of

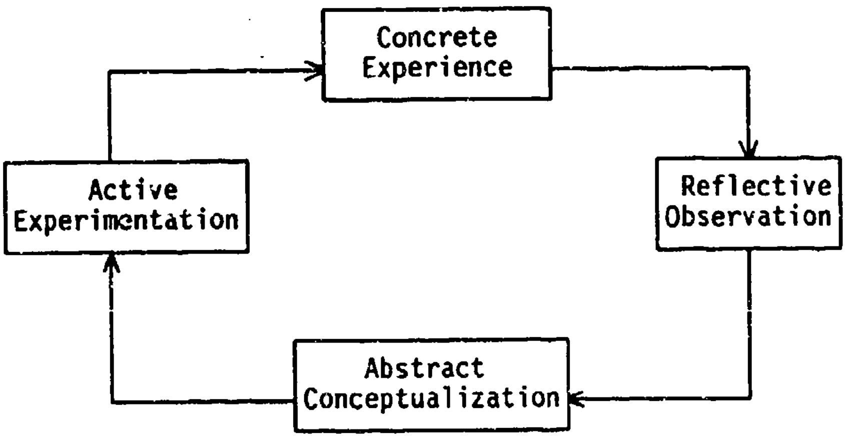

Figure 5-1. The learning loop. (See text for explanation).

instruction on facts and prerequisite knowledge of rules. Rather, problem solving or discovery is conceived of as the final step in a sequence of learning that extends back through the many pre-requisite learning stages that must have preceded it. The instructions given are important in helping the learner to properly structure the problem. If given correctly, instructions fulfill several functions:

1. They inform the learner about the nature of the expected performance, i.e., they define the learner's goal.
2. They can deliberately bring about the recall of certain subordinate rules.
3. They can be employed to "channel" or "guide" the learner's thinking, by emphasizing the direction for thought.

Guidance may vary in amount or completeness, but always stops short of completely describing the solution. Guidance should at least inform the learner of the goal of the activity and the general form of the solution; this is the minimum amount of guidance required if learning is to occur at all. More guidance may enhance or quicken problem solving but also runs the risk of limiting the range of hypotheses considered by the learner.

Ideally, in order to foster creativity, the teacher must create favorable grounds on which inductive leaps may occur. This would involve a learning environment in which individual differences in cognitive styles are recognized and addressed by individualized instructions. The instructions may adapt to the different learning styles by supplantation or transformation. The goal is to help the learner discover the higher-order rules for him or herself. But this is easier said than done.

Supplantation. Suppose that a student is asked to perform some task for which he is, as yet, unprepared. The basic process proposed for completing an incomplete learner/task link is supplantation. This is defined as the explicit and overt alteration or performance of a task requirement which the learner would otherwise have to perform covertly for himself. By employing an instructional treatment that supplants for learners the process they are unable to perform, a bridge is formed that completes the learner/task link and enables a successful performance. Thus, supplantation performs the required stimulus transformation which the learner was unable to perform himself. Conciliatory supplantation consists of altering the manner of presenting the task so as to remove the requirement with which the learner is having difficulty. Compensatory supplantation involves performing that requirement for the learner.

ICAI. Intelligent Computer Aided Instruction (ICAI) is a relatively new approach which applies AI techniques to training and instruction (Eberts and Brock, 1987). An example of a system which makes use of the ICAI approach is STEAMER (Hollan, Hutchins, and Weitzman, 1984). Developed by Bolt, Beranek, and Newman under contract to the Naval Personnel Research and Development Center (NPRDC), STEAMER is used to train Navy personnel in propulsion engineering. Because steam power plants are quite complex, it was determined that training should focus on helping the student develop a mental model of the system so that the student can mentally simulate how the system works. STEAMER's intelligent tutor helps students by providing suggestions, answering questions, and giving explanations. It also can analyze the student's misconceptions and guide the student toward a clearer understanding of the principles of propulsion engineering.

ICAI is still in its infancy. There are very few examples, other than STEAMER, in which ICAI has actually been applied to real world training. The cost and time to implement ICAI is high and likely to increase in the future (Eberts and Brock, 1987). In addition, much research into ICAI theory and technology will need to be carried out over the next few years in order to make this technology truly feasible. Since ICAI is compatible with the other concepts of use discussed in this report, it is hoped that ICAI can be incorporated as a long-range improvement to DECAID instructional delivery.

SECTION 6.0

DECAID CONCEPTS OF USE: SCENARIO PRESENTATION

INTRODUCTION

DECAID can also support training in CBR-D procedures and risk management factors in the context of a realistic operational scenario. The student will see displays and receive information in a manner and sequence similar to what would be presented in DC Central aboard ship. By tying together the elements of CBR-D training, and placing them in a context with other non-CBR-D factors, the student will be given the opportunity to integrate newly learned knowledge and begin to transfer learning from the classroom to the shipboard setting.

Additionally, DECAID scenarios may be thought of as "test beds". They provide a context within which to evaluate student learning, decision making styles, subjective likelihood assessments, and personal values. Student performance captured from scenarios might be catalogued and added to an actuarial data base which indicates areas in which students have problems transferring their training, describe distributions of responses to risk management decisions, and point out common misconceptions which students have. These data could then be used to guide DCA curriculum revision and expansion, indicate topics which may require greater emphasis during instruction, suggest individual remediation, and serve as a "qualifying" examination for DCA's.

It is interesting to further consider that the scenarios might serve as a test bed for trying out new decision aiding technologies and guiding further research. Within the scenarios, decision aids could be evaluated with respect to understandability, requisite skill level, convenience of data input and output, among other factors.

USE AND BENEFITS OF SCENARIO-BASED TRAINING

The Navy has, for many years, used scenario-based training as a means for providing a realistic context for the often disparate elements of fleet training and readiness. Fleet exercises, with few exceptions, are conducted with an assumed aggressor, the "orange nation" that has a defined set of objectives. The friendly or "blue" forces have a set of objectives to deter the "orange" forces and influence events toward an outcome favorable to the United States.

Against this backdrop, fleet exercises are conducted in anti-submarine warfare, amphibious operations, engineering, damage control, etc. For example, if a ship has a training requirement for a full-power run, the scenario my be set up such that it needs to make a high speed run to attain the proper geographic position. One purpose of embedding the full-power run in a scenario is to make the point that a ship has some ultimate purpose, an assigned mission to accomplish, and that it would be inappropriate to sacrifice that overall mission for the sake of a sub-objective. For instance, if a ship's mission is to protect a convoy, it would be inappropriate for that ship to steam off over the horizon chasing an enemy submarine; at some point, the appropriate thing to do is to break off the engagement and return to the convoy. Thus, once the basic procedures of prosecuting a sonar contact have been learned, the fleet exercise scenario provides the ship a chance for the ship to put those skills to use in their intended context.

In a similar manner, individual shore-based training has used scenarios to provide students with an opportunity to put the elements of training together in a realistic context to both integrate and test newly-acquired skills. War gaming is a prime example, but it is also used in training for tactical action officers, battle group staff training, and in single mission area training devices such as at anti-submarine warfare schools. The Damage Control Assistant course currently uses scenario-based training in a limited way in their DC Central mock-ups to give students the opportunity to integrate the elements of a subject area learned one at a time in the classroom.

Scenario-based training can be particularly beneficial in the area of CBR-D, an area which has long been criticized for its singular focus. CBR Defense is unique in that the measures required to protect the ship and crew from the adverse effects of lethal agents can cause considerable mission degradation in and of themselves. Simply dressing out the crew in gas masks and protective clothing without regard to what tasks they will have to perform, the cumulative effects of heat stress they must endure, and the additional task completion time they will need is suboptimal training of the worst kind. CINCPACFLT, as early as 1984, called for the overlay of CBR-D training on top of training in other mission areas. For instance, rather than exercise fleet CBR-D capabilities independently, conduct amphibious exercises with the added constraint of an "orange" adversary that has the will and capability to employ chemical munitions to oppose "blue". This overlay concept of CBR-D training has begun to occur in fleet exercises on both coasts as well as in ship refresher training.

As envisioned in it's DCA school application, DECAID would provide the capability to embed the elements of CBR-D in a broader context of other damage control (e.g. firefighting, flooding) as well as non-damage control factors (e.g. intelligence reports, ship mission requirements) about which the student would have to make time-critical decisions. Consequently, our concepts of use for scenario presentation include a "library" of scenarios. CBR-D need no longer be treated in isolation from structural damage to the ship. A chemical threat might be combined with a fire, simulating a CW hit with a penetrating shell. Flooding might be added to the CBR threat. The interaction among these multiple damage states and their implications for management decision making about crew, time and material resources could then be made apparent. The severity of damage could be tailored to provide a graded sequence of scenarios suitable for a broad range of students for the newly commissioned ensign to the seasoned senior officer. This would exercise the student in specific procedures previously learned in the classroom. It would also present contextual risk-management situations for which their is no clear "right answer" but in which learning takes place in understanding the possible consequences of decisions made.

METHODOLOGIES FOR SCENARIO-BASED CBR-D TRAINING

Student DCA's would be presented with an initial situation followed by a string of time-ordered events designed to exercise their decision-making abilities. To make the decisions required by the situation, they would have to rely on specific pieces of previously acquired procedural knowledge, plus make judgement calls on the more ambiguous risk management situations. The consequences of each decision would impact later events in the scenario. Examples of one possible Chemical scenario, and one possible Radiological scenario are included in Table 6-1 and Table 6-2. Note that each scenario is broken into six situations, each of which presents a rich slice of the decisions DCA's need to make at sea. None of the CBR-D decisions can be considered independently of the ship's mission, the environment, or other damage. One set of decisions is relatively straightforward, i.e. what material condition to recommend, what MOPP level to set. Another set of decisions are so complex they are termed "risk management dilemmas". These have no right or wrong answer, but the action taken will impact the scenario whichever decision is made. For example, in situation 5 of the sample chemical scenario (Table 6-1) the DCA needs to decide whether to rig shoring or decontaminate the CIWS launcher. If the CIWS launcher is deferred, the ship might sustain a direct hit later in the scenario. If the shoring is deferred, later action might cause a progressive flooding situation that could have been averted by proper shoring. DECAID will record whichever decision is made and feed it back into the scenario.

Naval operations in a CBR-D environment are likely to take place over the period of several days. Decisions regarding MOPP level or resource allocation made on day 1 may have no immediate impact, but a very severe one on day 3. Likewise, over the period of operations, the DCA may have long periods of relative inactivity punctuated by periods of intense crisis in response to enemy action. Accordingly, the training scenario can compress the time frame of a sustained operation, and present those nodes of intense activity as decision training "slices", jumping in time from the end of one to the beginning of the next. A three day CBR-D operation could thus be condensed, with the high points presented during a 1-2 hour training period.

Learning might be reinforced in a variety of settings. The instructor could stop the scenario momentarily and ask the student to reflect on the reasons for and consequences of a decision. The experiences of a group of students could be discussed in a seminar setting so that students could analyze the differences and similarities of their individual training sessions.

If instructors determine that a particular area needs more attention on the part of one or more students, an individual scenario slice might be run separately and repeatedly to reinforce a particular "lesson learned". In this mode, DECAID could also be used to test students on individual topics in the DCA curriculum. For example, a scenario slice could focus extensively on recognition of chemical agents and their properties, for the purpose of both drilling and testing students in that knowledge area.

After several classes of students have had the opportunity to interact with the DECAID scenario-based training, it is envisioned that instructors will begin to develop a sense for the different decision-making styles exhibited among students. Speed, information verification, and maintaining the big picture are some of the factors that may describe a decision "style". This can be presented to students as feedback, along with some insight as to which style is most appropriate for a specific situation.

SCENARIO DEVELOPMENT

Figure 6-1 illustrates both sources and target areas for scenarios within DECAID in particular, and for DCA training in general. The focal point for scenario generation must be instructors who are aware of both student needs and operational fleet requirements. In developing suitable scenarios for presentation by DECAID, instructors must start with the specific CBR-D learning objectives they desire to be included in that segment of the curriculum. With these in hand, secondary objectives may be included, either to reinforce deficient areas from elsewhere in the DCA curriculum, or to include as professionally interesting operational situations over which to overlay the CBR-D environment. Then, as operationally-experienced subject matter experts, they can construct a realistic scenario that encompasses each of their desired learning objectives. It is essential that scenarios be able to be modified locally to keep up to date with changes in curriculum emphasis, and fleet operating patterns. Thus a relatively small set of scenarios might be turned into a large library by:

- Including additional damage and threats
- Providing a different mix of threats
- Changing the time, circumstances, location, etc. of damage sustained
- Modifying outcomes ar initial conditions for the scenarios (e.g., different manning levels, equipment line-up, watertight integrity, material conditions)

It is worthwhile to note that the scenarios can influence the content of DECAID instructional delivery, and suggest areas where decision support is needed. The content and emphasis of scenarios might also impact the instructor's approach on emphasis in the classroom as well as the materials the students are given to study. Thus, scenarios might be a core resource, resident within DECAID, which can provide multiple benefits to improving decision making in DCA's.

It is envisioned that DECAID in it's on board training (OBT) version will be used periodically by DCA's to update their skills and refresh their knowledge about CBR-D, after they have reported to their ships. This is especially important because DCA students often serve in another billet aboard ship to get some experience before they actually relieve as DCA. Instructors at FTG Guantanamo Bay have reported that DCA's often begin REFTRA deficient in CBR-D skills such as radiation calculations or chemical agent symptoms. To help keep fleet DCA's up to date, SWOS could periodically send out new scenarios as part of the OBT program. These scenarios could also include the latest procedural guidance as an instructional delivery module prior to the star of the scenario, so that fleet DCA's are kept apprised of the latest developments on the rapidly changing field of CBR-D.

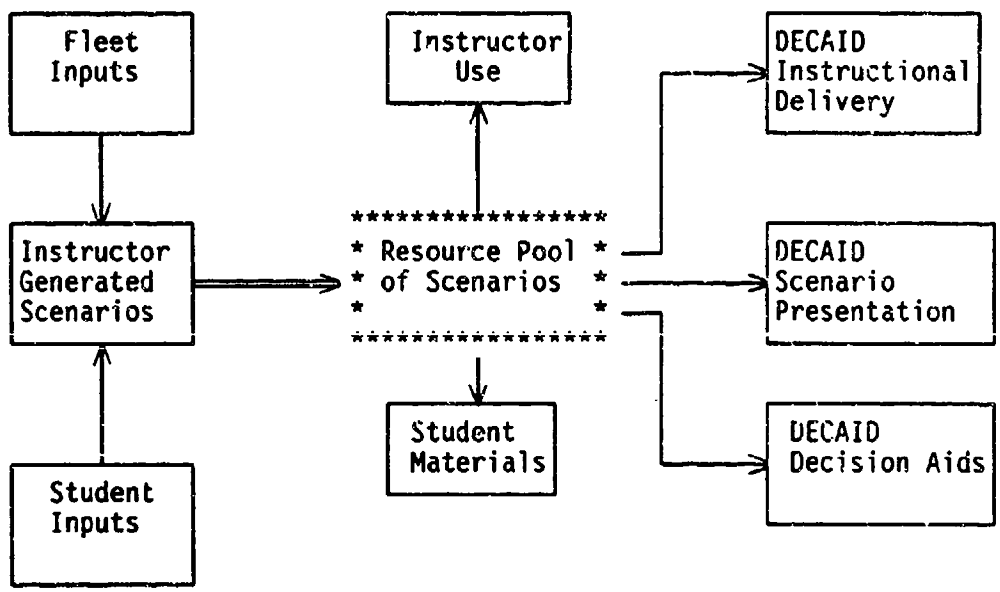

Figure 6-1. Sources of and target areas for DECAID scenarios.

Table 6-1

Example CW Scenario

Situation One: T-18hrs.

You are DCA aboard an FFG steaming in the North Arabian Sea, enroute to the Persian Gulf. You are approximately 150 miles off the south coast of Iran. The ship's mission is to rendezvous with a convoy of six reflagged Kuwaiti tankers, and with two other warships, escort them to Kuwait and back out to the North Arabian Sea. U.S intelligence has identified several Silkworm missile sites and speedboat bases within range of your proposed track. Intelligence reports also indicate that chemical warheads of Iranian manufacture have been transported to Silkworm sites.

DCA Decisions:

- Is a CW attack likely?
- What particular agents might be employed?
- Is the current weather favorable for an attack?
- What MOPP level should I recommend to the CO?
- Should certain watch stations be at relaxed MOPP?
- How will an agent be detected?
- Do I need to make any modifications to the CBR-D bill regarding posting detector paper?
- Do I recommend operating the water washdown system?

Risk Management Dilemmas:

- How do I manage the current inventory of CBR-D clothing and equipment to maximize protection, without risking running out before the operation is completed?
- How do I minimize the mission degrading effects of wearing protective clothing, including heat stress, and still maintain an adequate protective posture.
- What is the crew's state of training? Is it worth the time investment to conduct last-minute training now?
- How do I set up a watch rotation that will minimize heat stress casualties, yet provide maximum battle readiness over the long haul?
- What problems can I anticipate in 24, 48, 72 hours? Is there anything I can do now to prepare for them?

Situation Two: T-6hrs.

The convoy has just passed through the Straits of Hormuz. Intelligence reports that Iraq has just used "dusty mustard" to repel an Iranian ground attack near Abadan. There is a high likelihood that Iran will retaliate with a demonstration of it's newly improved CW capability within the next 48 hours. The average daytime air temperature is 97F with an injection temperature of 86F. Two heat stress casualties have been reported in the Engineering Dept. The convoy commander has ordered complete radio silence, so all communication will be visual.

DCA Decisions:

- What material condition should I recommend?
- What MOPP level should I recommend?
- Should we operate the water washdown system?
- Should MOPP be relaxed for Engineers?
- What routes should be used to break out stores etc.

Risk Management Dilemmas:

- The signal bridge performance has become critical to the mission. Can we afford to let them relax MOPP?
- Are the heat stress casualties in accordance with prior predictions? Do we need to reduce watch length and provide more rest? How do personnel limitations affect the ability to reduce watch lengths?
- How much longer can we sustain this readiness posture?
- Is the usage rate for CBR-D equippage in accordance with prior predictions? When will we run out?
- What is the impact of operating water washdown on other uses of firemain? Any equipment likely to drop off the line? How will that impact the ship's mission?
- How can I respond for the various requests for routes to break Condition Z in a way that maximizes watertight integrity without unduly hampering mission critical operations?
- What problems can I anticipate in 24, 48, 72 hours? Is there anything I can do now to prepare for them?

Situation 3: T-1hr.

The ship strikes a small floating mine, resulting in a split seam forward on the starboard side. Flooding is under control. Number one fire pump motor suffered salt water damage and is off the line. Electricians estimate a 12-hour ETR once the motor is rigged out and taken to the shop. Firemain pressure is 10 psi blow normal, and you have just had a report of a high temperature alarm in the radar equipment room. One signalman and one more engineer have become heat stress casualties and were taken to sickbay.

DCA Decisions:

- Reassess likelihood of attack
- Recommend material condition
- Recommend MOPP level and relaxations permitted

- Respond to requests for routes
- Recommend flooding boundaries
- Decide if flooding party needs assistance
- Determine effect of flooding on stability
- Determine solution to firemain problem(s)

Risk Management Dilemmas:

- Should electricians break watertight integrity to begin rigging out the firepump motor?
- Should flooding party remove IPE until flooding is under control?
- How can the limited firemain flow be managed to balance the needs for water washdown, auxiliary machinery cooling, air-conditioning plants etc.
- What problems can I anticipate in 24, 48, 72 hours? Is there anything I can do now to prepare for them?

Situation 4: T-0

CIWS destroys an inbound Silkworm missile off the starboard bow. The type of warhead is unknown. The force of the explosion loosened the patch and shoring on the split seam, which begins flooding again. The signal bridge reports another apparent heat stress casualty, but the report is ambiguous and incomplete.

DCA Decisions:

- What agent(s) has the ship been hit with?
- What information should be promulgated on first aid and buddy aid?
- Where is the best place for the CCA and Decon station?
- What is the best routing for casualties?
- What is the extent of contamination? How long can I expect it to remain a problem?
- Recommending flooding boundaries to repair 2
- Determine if flooding party needs assistance

Risk Management Dilemmas:

- What is the relative priority of the chemical agent and the flooding situation? Can we afford to neglect one until the other is under control?
- How should requirements for firemain be prioritized now?
- Can the ship deal with the damage control problem AND continue to perform its mission, or are all hands required to save the ship?
- Am I getting an accurate picture of what is really going on? Which reports need to be validated?
- What problems can I anticipate in 24, 48, 72 hours? Is there anything I can do now to prepare for them?

Situation 5: T+3

Three casualties are reported in Sonar, where gas masks were apparently removed without permission. Communications has been lost with Radio, investigators report the security door locked from the inside, but no response within. The CIWS launcher is contaminated with chemical agent and the C.O. wants it reloaded ASAP. The flooding is under control, but Repair 2 reports that the flooding team is having difficulty replacing the shoring, because of the impediment of protective clothing.

DCA Decisions:

- Casualty handling and routing
- Decontamination team routing
- Decon station traffic flow
- Material condition and MOPP recommendations
- Should assistance be provided for the flooding team?
- When to secure water washdown

Risk Management Dilemmas:

- How to manage limited manpower assets? Same crew needed to decon the CIWS launcher is working on the shoring.
- Can the ship continue it's mission or must operational personnel be diverted to damage control tasks?
- What to do about casualties in sonar and radio? Save them, save the ship, or keep the convoy mission going?
- What problems can I anticipate in 24, 48, 72 hours? Is there anything I can do now to prepare for them?

Situation 6: T+24

Steaming off the coast of Kuwait. The ship is still within range of possible attack, but all is quiet at the moment. All chemical agent has dissipated. There are numerous casualties, and everyone is hot and tired. Firemain pressure is low, work has not yet begun on #1 firepump. Flooding is under control, with shoring in place. The tankers are taking on cargo, and will be ready for the return transit in 24 hours.

DCA Decisions:

- Stability calculations and assessments
- After-action repairs
- MOPP and material condition
- Outside assistance required

Risk Management Dilemmas:

- How to coordinate the repair effort with the need to sustain a readiness posture in the face of a continuing threat.
- Should the crew take a breather or proceed smartly with the repair efforts and preparations for the return transit?
- Can the ship continue its mission without replacement manpower and equipment?
- What is the inventory of IPE and detector paper etc? Enough for the return transit? How to manage shortages?
- What problems can I anticipate in 24, 48, 72 hours? Is there anything I can do now to prepare for them?

Table 6-2

Example Radiation Scenario

Situation #1: T-6 hours

You are DCA aboard an FFG steaming with a Carrier Battle Group in the North Atlantic. Relations between Nato and Warsaw Pact nations have been deteriorating steadily for several weeks, and DEFCON Two has just been set. The Battle Group is enroute to the Norwegian Sea to counter a build-up of Scviet Naval Forces in that area. Your ship is on an ASW picket station, ten miles ahead of the carrier. A condition III steaming watch is set.

DCA Decisions:

- Recommend material condition
- Recommend MOPP level
- Remedial training effort needed?
- Test radiacs and washdown system?
- Issue personal dosimeters?
- Position area monitoring dosimeters?

Risk Management Dilemmas:

- How to balance defensive measures against requirements for the ship to maintain maximum operational readiness
- Can you test the water washdown system even though it interferes with topside tasks
- How will MOPP level affect heat stress, especially in engineering spaces.
- If you begin issuing CBR equipage, what is the chance you will run our of consumables, (i.e. canisters and protective overgarments) before the operation is completed?

Situation #2: T-30 min.

The carrier reports a regiment-sized Bear/Badger raid engaged by CAP two hundred miles to the east. Your ship goes to general quarters. The OTC advises that a nuclear attack is "probable".

DCA Decisions:

- Recommend material condition - Circle William?
- Topside personnel lay below? Which ones?
- Routing requests
- Recommend MOPP level
- Activate water washdown system?
- Increased damage control readiness? What?

Risk Management Dilemmas:

- Water washdown versus air defense stations topside
- Access to spaces versus watertight integrity
- Protection of carrier versus protection of own ship

Situation #3: T+0

The bridge reports a nuclear detonation approximately 10,000 yard away, in the direction of the carrier. Initial damage reports include a ruptured firemain in the repair three area, and a ruptured hydraulic line on the steering gear. The rudder is locked at right ten degrees. Firemain pressure aft is 50 psi.

DCA Decisions:

- Is the initial damage assessment accurate?
- Set/Relax Circle William?
- Personnel to deep shelter? Routing?
- Don Gas Masks?
- Level of initial radiation. Implications.
- Arrival of base surge

Risk Management Dilemmas:

- Water washdown versus other uses of firemain
- Reduction of radiation exposure versus mission accomplishment
- Repair of steering versus radiation exposure to personnel
- Circle William versus heat stress effects on personnel and equipment
- Accomplishing ship's mission versus damage control

Situation #4: T+30 min.

The bridge reports that the base surge appears to have engulfed the ship. The XO's pocket dosimeter indicates an accumulated dose of 25 rad. He wants to know the safe stay time for bridge personnel.

DCA Decisions:

- Approximate topside and below-decks radiation intensities
- Arrival of fallout
- Cessation of fallout
- Accumulated dose for repair locker personnel
- Safe stay time for exposed personnel
- Recommend C.O. increase MPE?
- Initiate rapid internal survey
- Initiate rapid external survey
- Routing requests

Risk Management Dilemmas:

- Accept short term radiation sickness so that ship can continue mission?
- Begin survey and decon process or wait for another attack?
- Long term radiation effects versus keeping personnel protected to enhance future performance
- Facilitating critical movement within the ship versus limiting possible spread of contamination

Situation #5: T+1 hour

The results of the rapid internal survey indicate a hot spot on the fantail and another in the vicinity of the CIWS launcher. the firemain rupture has been bypassed, and the steering casualty repaired.

DCA Decisions:

- Send out rapid external survey?
- Safe stay time for survey team
- Exit point and reentry point
- Route to Decon Station
- Designate casualty collection station
- Routes for replacement of exposed personnel
- Secure water washdown?

Risk Management Dilemmas:

- Decon personnel or keep interior spaces clean?
- ecover from last attack or prepare for next one?

#6: T+24 hours

decontamination has been completed, with radiation readings at an acceptable level topside, with the exception of the CIWS launcher, which was not adequately covered by the water washdown system. Two personnel are in sickbay with reported nausea symptoms. It is sea state three. The battle group is continuing it's transit to the Norwegian Sea. The OTC considers nuclear attack "possible".

DCA Decisions:

- Long term decon plan
- Safe stay times/rotation plan for CIWS loading personnel
- Reccommended MOPP
- Recommended material condition
- Predict future radiation casualties
- Redeployment of personnel and detectors for another attack

Risk Management Dilemmas:

- MOPP versus long term heat stress
- Use personnel to repair or maintain defensive posture?

SECTION 7.0

DECAID CONCEPTS OF USE: DECISION AIDING

INTRODUCTION

Human decision makers have limitations on how fast and accurately they can gather information, process that information to arrive at a situation assessment, develop a course of action, and carry it out. These limitations include constraints on perceptual, short-term, and long-term memory; mental arithmetic; consistency of subjective estimates of likelihoods and values, and biases in inference. Training can enhance decision making performance through instruction and practice. Decision aids can also improve the quality of decisions through compensation for biases and cognitive limitations. Decision aids may be considered complementary to training in this respect (Nickerson and Feehrer, 1975). Therefore, a comprehensive concept of use for DECAID must include provision for the system to provide decision aiding as well as training.

Decision aids serve three related purposes: description, prediction, and control. Decision aids can describe a process or present preplanned action alternatives to the decision maker. When aids say something about the future state of a process, then they are serving a predictive function. Finally, when such predictions (or descriptions) are used for controlling the outcome of some process, then these decision aids support the control of that process. A decision aid, of course, may reflect all three purposes.

Zachary (1986) has prepared a taxonomy of decision aiding technologies based on the kinds of support that decision aids give human decision makers. Figure 7-1 illustrates the structure of the taxonomy. Process models support the prediction of complex processes and may include mathematical equations (both statistical and deterministic), computer simulations, and physical models. Value models integrate individual data (e.g., probabilities and utilities for various events) and criteria across aspects or alternatives to arrive at consistent choices about response options, thus supporting control. Information control techniques serve a primarily descriptive role in supporting the storage, access, retrieval, organization or monitoring of data. Representational aids also support the description and control of a decision

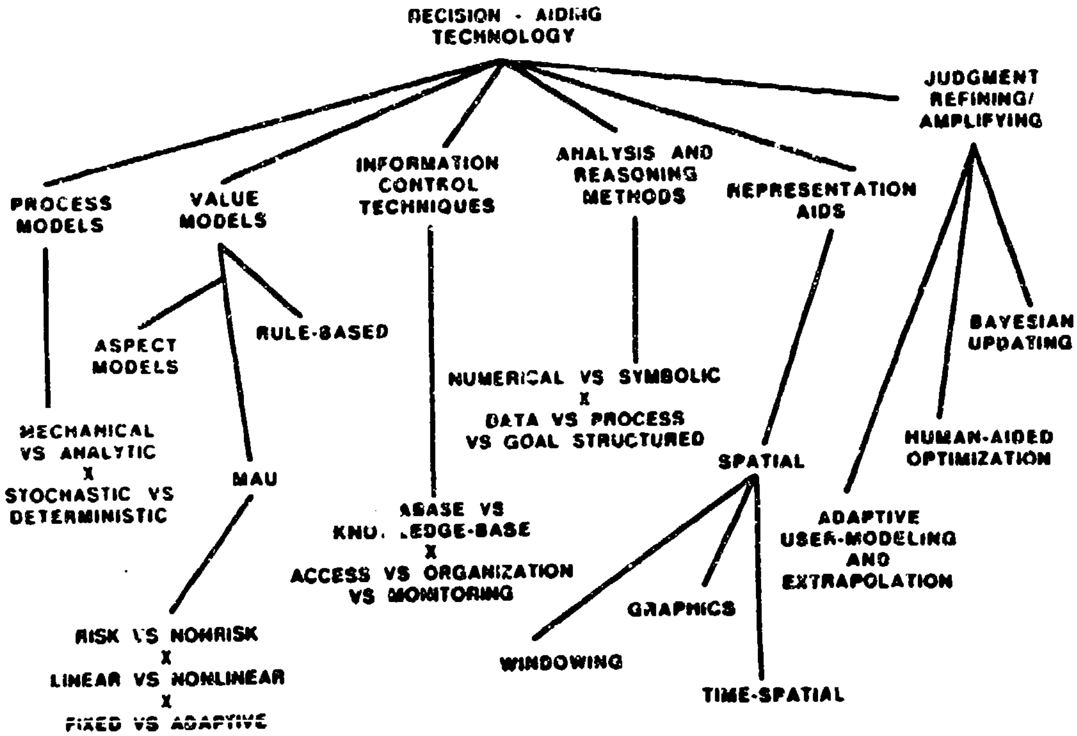

Figure 7.1. Decision support taxmonomy (Source: Zachary, 1986)

problem, often by means of visual displays which illustrate aspects of a decision problem which cannot be fully appreciated otherwise. Analysis and reasoning aids can provide problem-specific expertise to the decision maker in the form of an expert system or through operations research techniques. Finally, judgement refinement and amplifying technologies, such as Bayesian updating, try to capitalize on human heuristics and intuitions by performing smoothing, refinement, or extrapolation calculations on the human's intuitive 'initial guess'. Additional details on the various technologies are contained in Zachary (1986).

The above taxonomy categorizes decision aids by support function, i.e., by what they do. Decision technologies may also be considered with respect to form, i.e., by how they work. Relational data base methods such as those used in SNIPE, for example, can alleviate memory burden and improve the probability of accurate and timely recall of firefighting information for the decision maker. Interactive graphics capitalize on our highly developed 2-D and 3-D pattern recognition capabilities to perceive and process information rapidly (Foley and van Dam, 1982); a damage control example might be a fast-time video display of contaminant spread through a ventilation system. Functional models such those used in stability calculations provide deterministic solutions to deterministic systems of equations which may be used for process control or resource management. Statistical models, such as a regression equation which predicts heat stress given MOPP level, climate, workload, etc., might provide the DCA with decision support in the form of probabilistic assessments of crew endurance based upon a set of observable or controllable factors. Monte Carlo simulations mimic the behavior of systems which are not suitably described by analytical methods. Finally, artificial intelligence/expert systems (AI/ES) capture human expertise, often in the form of condition-action rules, which may provide problem-specific assistance to a decision maker. The type of decision aiding technology to use in a particular application or situation is highly context-dependent. However, it is probably safe to say that expert systems and simulations generally are more difficult to design, build, verify, and validate than statistical or functional models, which in turn may be more demanding to construct that certain types of displays and data bases. It is equally safe to say that decision aids may be built which incorporate several methods and technologies into the same tool (e.g., a deterministic model operating upon data base information to drive a graphical display).

Decision aids can promote learning. For example, a checklist is a decision aid which alleviates memory burden to insure accurate, complete, and properly sequenced activities. In addition, repeated exposure to a checklist may promote learning of the items on it; such learning is termed "incidental" because it is not the user's intent to learn from the list but rather to use the list to do a job. Expert systems can, in principle, also promote learning by means of an explanatory subfunction in which the system explains how it arrived at a conclusion/recommendation. Use of a linear regression model could, over repeated exposure, instill its relative weighing structure in the human decision maker. Such decision aids are desirable to the extent that, if DECAID should become inoperable, the DCA must still perform the previously aided functions.

Some decision aids may also stifle learning. A calculator is a decision aid to the extent that it alleviates the requirement to perform mental arithmetic. Yet, its proliferation has significantly affected arithmetic skills by eliminating opportunities to practice mental arithmetic. The development of printing and photocopying has improved accurate recall of information but diminished the need for rote memorization, a common (and highly regarded) skill among previous generations. Finally, a decision aid which puts data together into a composite picture may reduce the user's capacity to do so on his own. The design guideline implied by these examples is that decision aids should be employed for applications which are sufficiently complex that people do not perform them well (i.e., require speed or precision beyond that which a human might provide alone or unaided).

Some decision aids have no bearing on learning because the decision task cannot be learned to mastery in the first place. An example of this category is a simulation of a complex system. The outputs of such a simulation can provide decision aiding information but may be sufficiently intricate that the decision maker does not "learn" to simulate it in his or her head. The simulation does not explain itself; it simply does a job which a human being cannot do (well). Another example may be the stability calculations required under conditions of flooding; it appears that such calculations often simply cannot be performed manually in an acceptable length of time to adequately support decision making in the face of this threat.

To sum up, the following points may be reiterated. Decision aids serve descriptive, predictive, and control purposes. They may be categorized by both the function they support and by the form they take. They may help or hinder unaided human decision making. They may also be fully complementary or compensatory to decision training in assisting in the completion of tasks which cannot be trained to mastery due to human cognitive limitations, task demands, or other extenuating factors.

POTENTIAL DECISION AID APPLICATIONS FOR DECAID

The Navy has recognized the complexity of the DCA's job and the need to provide some automated decision aiding. For example, in a 1982 letter to the Chief of Naval Operations (CNO), for instance, RADM Bulkeley stated

> "Most ships continue to manually determine their stability calculations which is a tedious process. Recommend ships be outfitted with small computers to facilitate their stability calculations. Auxiliaries, Aircraft Carriers and large surface combatants are several ship classes that would benefit from this improvement."

DECAID is intended to be a training system but because decision aiding is complementary to decision training, the opportunities for DCA decision aiding cannot be ignored. Part of the instructional system development process should specify what tasks should be trained, what tasks should be aided, and what tasks might be profitably both trained and aided. While such an analysis is outside the scope of the present effort, several decision aiding applications were suggested during the course of this project. These initial concepts, depicted in Figure 7-2, are discussed below.

Information Retrieval Systems

Information Retrieval Systems support the storage, retrieval, and organization of information needed for decision making. Such systems, when properly designed, compensate for human memory limitations and provide different "views" of data which can be tailored to the situation at hand. An information

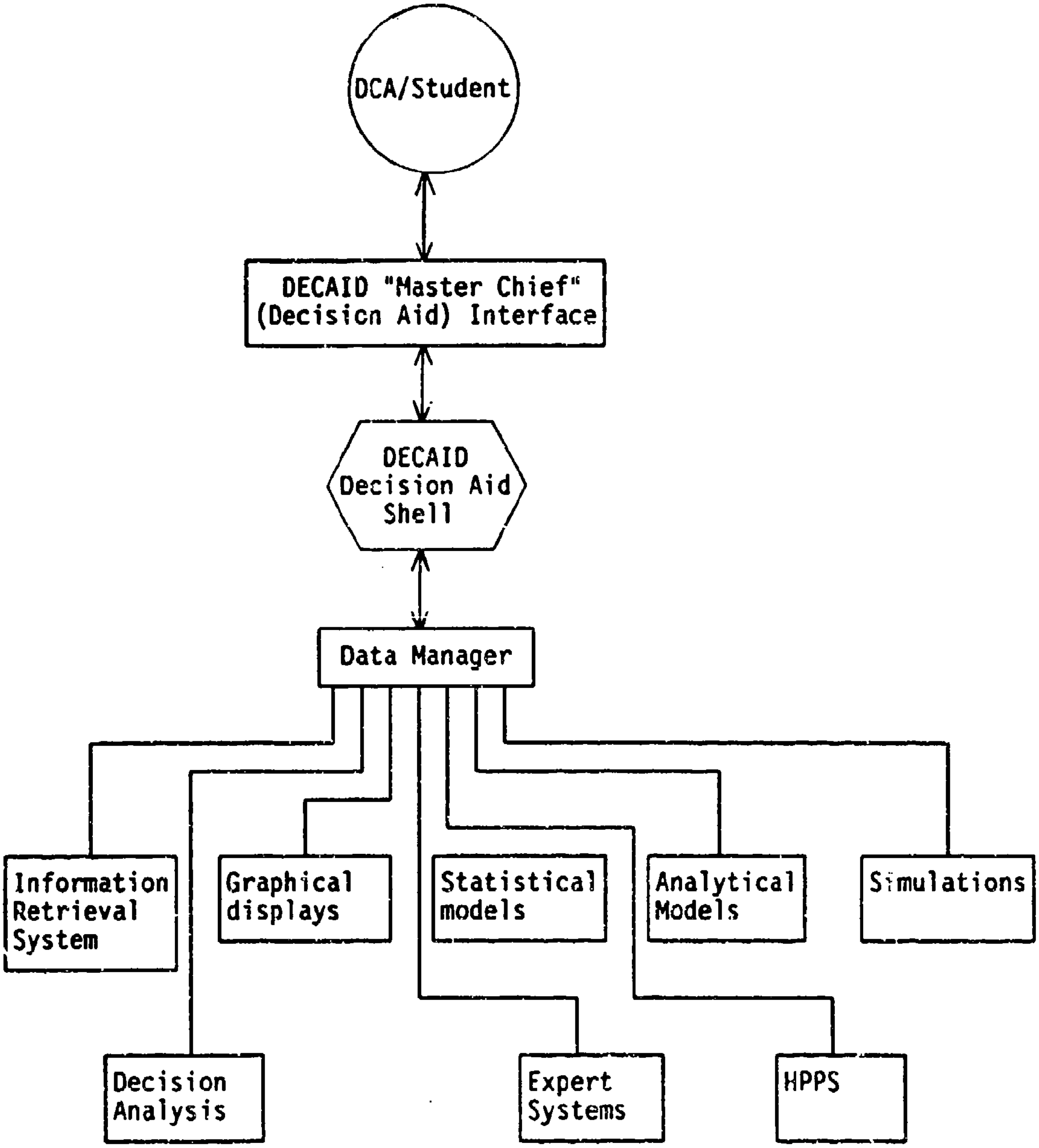

Figure 7-2. DECAID "Master Chief" proposed decision aiding modules.

retrieval system for the DCA might include storage of look-up tables, equipment supply lists, various bills, or virtually any information currently available in various documents used by the DCA. By means of effective indexing (Data Base Management) strategies, needed information could be, literally, at the DCA's fingertips.

A prime example of the use of an information retrieval system for DCA application is the system SNIPE (Bihr, 1987), which supports the DCA's firefighting duties by means of detailed descriptions of ship compartments, their relationship to other compartments, and their firefighting equipment status.

Graphical displays

Humans have a tremendous capacity to visually process information. Computer graphics or other visual displays which capitalize on this capacity can be effective decision aids. Ship Damage Control (DC) plates are a good example of a graphical display which aids the DCA in decision making. With automated equipment, the DCA might be given graphical overlays of the DC plates which visually indicate the progress of damage (or repair) in various parts of the ship. Time-based graphics on the DC plates might, for instance, present the spread of contamination over some specified time period, given existing conditions. Multiple overlays of ship subsystems and a "graphical closure log" might be used to support decisions on, say, rigging a jumper to compensate for a ruptured firemain and restore the Water Wash Down (WWD) system. Pop-up windows might also be used to present alphanumeric information alongside the graphic to provide the DCA with both text and the spatial context in which that textual information "fits". Various statistical graphics might be presented on available ship supplies, expected safe stay times under radiological conditions, and so on.

Statistical Models

Certain computational models can be used to aid the decision maker by concatenating various information sources and providing a predicted outcome or assessment. In the case of the DCA, for example, statistical models of human performance may be used to predict the speed, accuracy, or endurance of crew members under various conditions of MOPP, heat stress, and operational task (see Battelle, 1988 for a review of such models). Probabilities could be attached to, say, different watch lengths with respect to heat stress hazards and thus provide decision support for setting watch length under conditions of high thermal burden. Alternatively, if increased time is needed to complete critical shipboard operations in MOPP gear, then model outputs could help the CO with this time management problem.

Analytical models

A variety of quantitative approaches from operations research (OR) (cf. Hillier and Liberman. 1986) might be used to aid the decision maker in optimizing the use of limited resources in the face of competing demands. For example, the DCA must maintain a closure log and develop routes to decontamination stations and access to various parts of the ship. A routing algorithm which attempts to minimize distance or maximize watertight integrity with due consideration to constraints such as flooded/contaminated compartments would be helpful in expediting this decision problem. Another classic OR problem is control of inventory. Inventory models might be applied, for instance, to control the use of MOPP gear over an extended period. Yet another class of OR tools are PERT/CPM methods for controlling a project; in CBR defense, a 'project' may involve casualty control, decontamination, or containment.

An application of deterministic functional models may be found in the stability assessment module of a system like BALLAST. BALLAST calculates the required stability and buoyancy equations to arrive at recommendations for maintaining acceptable ship list and trim (Williams, 1986). Given the difficulty of performing such calculations manually, BALLAST offers the potential of significant time savings for a time-critical crisis, i.e., stability and flooding casualties.

Decision analysis

Decision analysis is another set of statistical techniques which attempts to quantify subjective assessments of likelihoods and consequences, appropriately weight the various factors which enter into a decision, and then optimally synthesize that information into an ordered evaluation of decision options from which the decision maker may then choose (von Winterfeldt and Edwards, 1986). In the case of the DCA, risk management decisions might be aided using techniques from decision analysis.

Simulations

Computer simulations of complex processes may be helpful in providing useful information or assessments to the decision maker or in providing recommended courses of action to pursue. DECAID, for example, might make use of a fast-time model of progressive flooding based on existing conditions; such a model might then be used for planning appropriate countermeasures. A sequential network model of a shipboard operation might be used to indicate the time required to perform that job under relevant conditions of MOPP, weather, and equipment status. Tijerina and Treaster (1987) as well as Treaster and Tijerina (1988) report the development of a Micro SAINT simulation of the CIWS loading operation with a three-man crew. Other applications might also be developed.

Expert Systems

In the evolving field of artificial intelligence, great interest has been focussed on the development and implementation of expert systems. Weiss and Kulikowski (1984) define an expert system as one that solves real-world, complex problems using a computer model of expert human reasoning, reaching the same conclusions that the expert would reach if faced with a comparable problem. An expert system for the DCA, for example, might include: rules for handling fires (developed from individuals who had handled fires well); flooding guidance (provided by a system created from the inputs of a stability and buoyancy expert and/or DCAs who had prevailed over flooding situations); a tailored CBR plan (offered by an expert system developed from people with experience in toxic spills, nuclear physics, or disaster preparedness).

At a minimum, the development of a viable expert system requires the following (see Hayes-Roth, Waterman, and Lenat, 1983; Waterman, 1986 for more details):

- one or more experts who are willing to cooperate in the system development,
- a knowledge engineer who can debrief the expert of his or her knowledge,
- a software tool (expert system shell) to hold and operate on the extracted expertise as well as allow for updates to the knowledge base to assure state-of-the-art expertise.

A common approach to building expert systems is to construct data bases of IF-THEN (situation-action) rules and procedures for searching through them to arrive at decisions or recommendations based on a set of available inputs.

Despite the allure that AI/expert systems currently enjoy, there are several reasons why expert systems technology should be approached with reservation. First, it can be difficult to find experts, especially in the area of CBR defense. It might be possible to take a more comprehensive view of CBR-D damage control and identify subject matter experts in flooding, firefighting, toxic spill clean-up, and so forth, but this is anticipated to be a time-consuming and expensive venture. Second, knowledge engineering remains a bottleneck in the expert system development process (Waterman, 1986). Many techniques exist for debriefing experts, including interviews, questionnaires, protocol analysis, simulated case studies, and structured walk-throughs (Hart, 1986). The difficulty is that much of expertise is based on tacit knowledge (i.e., knowledge the expert cannot articulate) and the currently available methods are 'weak' when it comes to extracting such knowledge. Third, problems of bias may plague the expert so that he suggests rules which actually have no bearing on actual problem solving. Fourth, verifying and validating an expert system is problematic because one cannot bench-test it against all cases of interest to determine if it works as expected. Fifth, there is the problem of divergent individual values. An expert system may embody the values of the expert it was modeled after, but these values may be inconsistent with those of the decision maker using the system; a good example in the damage control setting is the relative value placed on individual crew safety. Sixth, there is the issue of individual responsibility. If the DCA makes use of an expert system and the outcome is disastrous, who is to be held accountable

... the DCA or the machine? These caveats should not be taken to mean that we believe useful expert systems cannot be built for DECAID. Rather, it seems prudent to attempt to use other decision aiding technologies to best advantage and consider expert systems as a potential addition in future versions of DECAID. In the future, it may become feasible to develop an expert system for the DCA and CBR-D operations which will provide truly powerful capabilities and growth potential.

DECISION AIDS AND THEIR TRAINING IMPLICATIONS

Decision aids themselves have a training requirement; simply put, the officer must learn how to use the aid effectively. Due to its multifaceted nature, the requisite training might be factored in as part of the training offered by DECAID. Such training must cover instruction on data/command entry, data display conventions/options, sequence control, and user help; most importantly, however, is training on the interpretation of output. While the first areas should involve only modest amounts of training (if the user-computer interface is well designed), interpretation of output can be quite involved and complex.

Understanding what a decision aid is telling you requires you be familiar with: a) the problem under consideration; b) the principles being applied to solve the problem; c) specifics about the nature of the output the decision aid provides; and d) decision aid limitations, i.e., precision and speed limitations, boundary conditions, and what other information also bears on the decision to be made. Thus, a system like BALLAST will not eliminate the need for instruction in stability and buoyancy in the DCA course; rather, it redefines the training requirements associated with stability and buoyancy. A statistical model of crew performance requires an understanding of certain concepts in probability and statistics (e.g., expected value, confidence intervals, prediction bounds, cumulative distributions, etc.); without these, output from such models cannot be properly interpreted and applied in decision making. Just as map reading does not come naturally to many people, so training must be provided for getting the most information from a representational aid. Understanding the organization and indexing of a relational data base requires training and experience to allow the user to develop a suitable mental model of the material contained in the data base; failure to do this can lead to misuse or disuse of the data available. These few examples are sufficient to indicate that any concept of use involving decision aids also includes a training requirement to teach the aid's proper use within the context for which it was developed.

SPECIAL TOPIC: A CBR-D HUMAN PERFORMANCE PREDICTION SYSTEM (HPPS)

One area in which decision aids may offer truly innovative assistance and enhanced capability to the DCA and other naval officers is in the area of human performance prediction under conditions of CBR defense. A great deal of research is currently under way to develop models and data bases of human performance under such conditions so that aids may be developed which help officers make effective command and control decisions in this novel and demanding environment. Heat stress, the encumbrances of MOPP gear, unit resiliency in the face of personnel casualties, chemical agent effects on human performance, effects of pretreatment and antidotal drugs, and the implications of sustained operations/continuous operations (SUSOPS/CONOPS) are but a sample of the types of human performance problems the Department of Defense (DoD) is currently investigating. As our understanding of these aspects of CBR-D grows, it seems prudent to integrate such models and data bases into a coherent prediction system. Models and data bases addressing crew performance could provide realistic outputs for training scenarios such as those contemplated for DECAID as well as to enhance existing systems such as NAVTAG (Naval Tactics Game) and ENWAGS (Enhanced War Gaming System). Additionally, the prediction system could provide predictions and support to decision making about personnel, manpower, watch length, and crew attrition impacts, among others. DECAID could be one system which hosts such models and data bases. Similarly, DECAID could serve to focus research efforts in the physiological and psychological effects associated with CBR defense to meet specific training and aiding needs.

A general framework for organizing human performance models and data bases is provided in Table 7-1, based on the notion of a Performance Shaping Factor (PSF) (Swain and Guttmann, 1983). A PSF is any factor that influences human performance and three broad categories are defined in the figure: external

Table 7-1

Some Performance Shaping Factors (PSFs) in Human-Machine Systems

EXTERNAL PSFs		STRESSOR PSFs	INTERNAL PSFs
SITUATIONAL CHARACTERISTICS: THOSE PSFs GENERAL TO ONE OR MORE JOBS IN A WORK SITUATION	TASK AND EQUIPMENT CHARACTERISTICS: THOSE PSFs SPECIFIC TO TASKS IN A JOB	PSYCHOLOGICAL STRESSORS: PSFs WHICH DIRECTLY AFFECT MENTAL STRESS	ORGANISMIC FACTORS: CHARACTERISTICS OF PEOPLE RESULTING FROM INTERNAL & EXTERNAL INFLUENCES
ARCHITECTURAL FEATURES QUALITY OF ENVIRONMENT TEMPERATURE, HUMIDITY, AIR QUALITY, AND RADIATION LIGHTING NOISE AND VIBRATION DEGREE OF GENERAL CLEANLINESS WORK HOURS/WORK BREAKS SHIFT ROTATION AVAILABILITY/ADEQUACY OF SPECIAL EQUIPMENT, TOOLS, AND SUPPLIES MANNING PARAMETERS ORGANIZATIONAL STRUCTURE (e.g., AUTHORITY, RESPONSIBILITY, COMMUNICATION CHANNELS) ACTIONS BY SUPERVISORS, CO-WORKERS, UNION REPRESENTATIVES, AND REGULATORY PERSONNEL REWARDS, RECOGNITION, BENEFITS	PERCEPTUAL REQUIREMENTS MOTOR REQUIREMENTS (SPEED, STRENGTH, PRECISION) CONTROL-DISPLAY RELATIONSHIPS ANTICIPATORY REQUIREMENTS INTERPRETATION DECISION-MAKING COMPLEXITY (INFORMATION LOAD) NARROWNESS OF TASK FREQUENCY AND REPETITIVENESS TASK CRITICALITY LONG- AND SHORT-TERM MEMORY CALCULATIONAL REQUIREMENTS FEEDBACK (KNOWLEDGE OF RESULTS) DYNAMIC vs. STEP-BY-STEP ACTIVITIES TEAM STRUCTURE AND COMMUNICATION MAN-MACHINE INTERFACE FACTORS: DESIGN OF PRIME EQUIPMENT, TEST EQUIPMENT, MANUFACTURING EQUIPMENT, JOB AIDS, TOOLS, FIXTURES	SUDDENNESS OF ONSET DURATION OF STRESS TASK SPEED TASK LOAD HIGH JEOPARDY RISK THREATS (OF FAILURE, LOSS OF JOB) MONOTONOUS, DEGRADING, OR MEANINGLESS WORK LONG, UNEVENTFUL VIGILANCE PERIODS CONFLICTS OF MOTIVES ABOUT JOB PERFORMANCE REINFORCEMENT ABSENT OR NEGATIVE SENSORY DEPRIVATION DISTRACTIONS (NOISE, GLARE, MOVEMENT, FLICKER, COLOR) INCONSISTENT CUEING	PREVIOUS TRAINING/EXPERIENCE STATE OF CURRENT PRACTICE OR SKILL PERSONALITY AND INTELLIGENCE VARIABLES MOTIVATION AND ATTITUDES EMOTIONAL STATE STRESS (MENTAL OR BODILY TENSION) KNOWLEDGE OF REQUIRED PERFORMANCE STANDARDS SEX DIFFERENCES PHYSICAL CONDITION ATTITUDES BASED ON INFLUENCE OF FAMILY AND OTHER OUTSIDE PERSONS OR AGENCIES GROUP IDENTIFICATIONS
JOB AND TASK INSTRUCTIONS: SINGLE MOST IMPORTANT TOOL FOR MOST TASKS		PHYSIOLOGICAL STRESSORS: PSFs WHICH DIRECTLY AFFECT PHYSICAL STRESS	
PROCEDURES REQUIRED (WRITTEN OR NOT WRITTEN) WRITTEN OR ORAL COMMUNICATIONS CAUTIONS AND WARNINGS WORK METHODS PLANT POLICIES (SHOP PRACTICES)		DURATION OF STRESS FATIGUE PAIN OR DISCOMFORT HUNGER OR THIRST TEMPERATURE EXTREMES RADIATION G-FORCE EXTREMES ATMOSPHERIC PRESSURE EXTREMES OXYGEN INSUFFICIENCY VIBRATION MOVEMENT CONSTRICTION LACK OF PHYSICAL EXERCISE DISRUPTION OF CIRCADIAN RHYTHM	

* Some of the tabled PSFs are not encountered in present-day NPPs (e.g., G-force extremes) but are listed for application to other man-machine systems.

PSFs, stressor PSFs, and internal PSFs. External PSFs are factors that operate outside the individual crew member and include variables such as climate, watch schedule, physical task demands, equipment characteristics, and procedures. In the present context, stressor PSFs include psychological stress, sleep deprivation, CBR agents, ship motion, and heat stress. Internal PSFs operate within the crew member and include individual training (e.g., speciality ratings) and experience, current skill level, physical fitness, and attitudes. It is apparent that there are a great many PSFs which might be modeled. It is perhaps less apparent that PSFs can also be highly interdependent. For example, an external PSF (e.g., hot and humid climate) can induce a stressor PSF (e.g., heat stress), the severity or onset of which is mediated by an internal PSF (e.g., individual level of physical fitness). The number of and inter-relatedness among PSFs make human performance prediction challenging at best.

There are obviously a great many PSFs which might be considered for DECAID human performance prediction. Therefore, it is useful to identify a subset of PSFs which might be investigated first for application to CBR defense. We have used the SOURCE-PATH-RECEIVER Model (see Figure 7-3), borrowed from industrial hygiene (Olishifksi and McElroy, 1971), to let us identify a subset of PSF 'modules' which are highly relevant to crew performance under CBR-D conditions. Each module of the Human Performance Prediction System (HPPS) is described below.

The SOURCE portion of the HPPS characterizes the CBR threat as it reaches the ship as well as any factors which mitigate the initial concentrations with which the crew would have to contend. For example, Threat/Hazard models and data bases would, ideally, describe the physics of different CBR agents in (appropriate) terms such as volatility, vapor pressure, solubility, minimum lethal dose, density, melting point, boiling point, and neat vs. thickened. Such models and data bases might also include, subject to available intelligence data, the prior odds that specific agents would be would be used against U.S. forces by specific enemies, delivery modes (air burst missiles, penetrating rounds, spray tanks, etc.), volley sizes, and munitions circular error probabilities (CEPs). Deposition and weathering models, on the other hand, would predict the initial concentrations based on air flowing past the ship, weather conditions, if the water washdown (WWD) system is on or off, breach

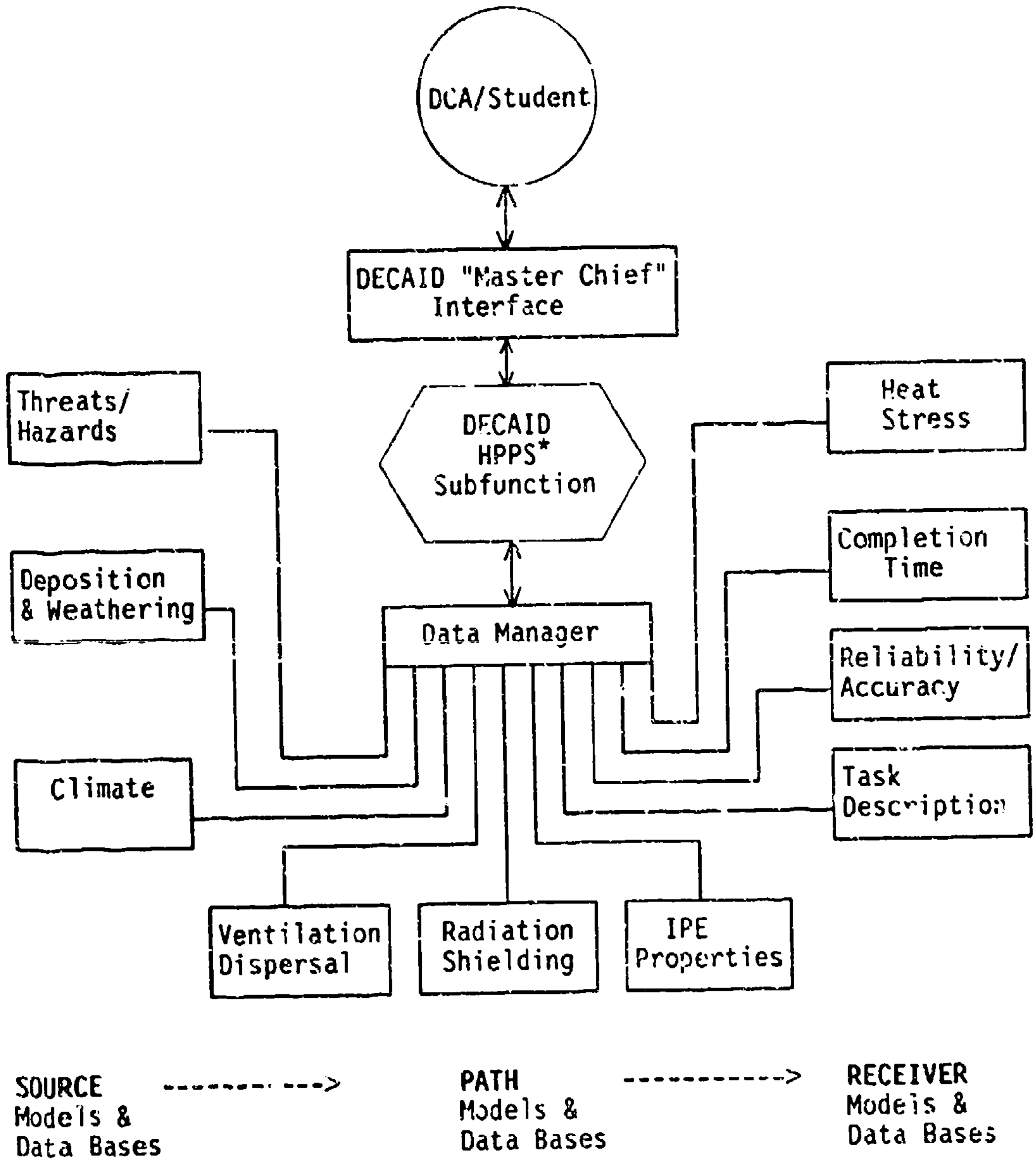

Figure 7-3. Conceptual framework for the Human Performance Prediction System (HPPS*) subfunction within DECAID's "Master Chief" (Decision Aid function), derived from the SOURCE-PATH-RECEIVER model.

in the hull vs. steaming through a chemical cloud, and the distribution of contaminant about the ship (e.g., aft on weather deck). Climate modules would provide realistic sets of weather indications and trends for particular locales and seasons.

Given an appraisal of the source of contamination, PATH models and data bases attempt to describe what happens over the course between contamination and crew. Ventilation models, for example, would describe the ship's internal air circulation in terms of flow rates, direction of flow, the impact of material condition (e.g., CIRCLE WILLIAM), air volumes per compartment, and ship layout in order to arrive at dose concentrations in different compartments over time. Radiation shielding models or data bases would provide an indication of the protection factor afforded by decks and hull, distance to the radiation source, type of radiation (alpha, beta, gamma, etc.), and half-life of an agent. Individual Protective Equipment (IPE) models or data bases would represent the human factors of MOPP gear, OBA suits, MCU-2P masks, and other protective gear in (appropriate) terms such a "clo" units (a measure of thermal insulation), weight, breathing resistance, permeability to agents, eyepiece optics, etc.

The RECEIVER part of the model indicates what impact the SOURCE stressors, as influenced by the PATH factors, have on crew performance at specific tasks. Task description data bases would describe critical shipboard operations in terms of their associated tasks, manning (crew size and ratings), allocation of tasks across crew members, sequential and simultaneous order of tasks (as in a network of integrated tasks), completion time and accuracy criteria, statistics on actual completion times and accuracy (averages and variances), characterization of the operation in terms of physical, perceptual, cognitive, and psychomotor requirements (perhaps by means of a taxonomy), and frequency of the operation. Individual human performance might be characterized in terms of endurance (availability to engage in a shipboard operation over time), speed (time to complete an operation or task), and accuracy (the reliability with which a task may be correctly completed). Given that the most serious threat to continuous operations in MOPP gear is heat stress, predictive models of heat stress could provide some indication of crew member endurance, i.e., how long crew members could work under specified conditions before the probability of heat stress casualties became unacceptably high. Expected completion times, task time multipliers, or time increments could provide some indication about how much longer a particular shipboard operation will take given a specified CBR-D scenario. Human reliability models and data bases could provide some indication about task accuracy which might be expected under specified conditions. Moving from individual to crew performance, attrition models could predict the ability to sustain/continue operations given a specified matrix of crew cross-training. Taken together, this 'suite' of models and data bases provides the conceptual basis for a powerful and practically useful system of human performance prediction which can aid the ship CO (as well as the DCA and other officers), to more effectively manage their human, time, and materiel resources under conditions of CBR defense. (Models and data bases which address these various aspects of human performance are discussed in Battelle, 1988). The proposed system revolves around a shell and data manager which provides the architecture for:

- data/command entry,
- interaction among various models and data bases (data passing),
- data display, and
- sequence control.

It is expected that the Human Performance Prediction System (HPPS) within DECAID will provide comprehensive and integrated decision support output regarding crew performance in the CBR-D arena. To provide some flavor for what it meant by 'integrated', consider the following scenario. A ship is operating in the Persian Gulf under conditions of high heat, high humidity, and no wind. Intelligence alerts the ship to a high probability chemical weapons threat over the next 4-hour period. In order to prepare for this threat, the CO asks the DCA to advise him on the human performance impacts of setting MOPP IV. The DCA might engage DECAID's HPPS facility and enter the current weather conditions, MOPP level of interest, call up critical shipboard operations which must continue over the 4-hour period, and so on. Based on the models and data bases available in DECAID, the DCA receive might receive output on:

- probability of heat stress casualties as a function of time topside or in engineering spaces;
- increase in time to perform critical shipboard tasks (e.g. topside weapon loading, line handling, signal bridge activities, shipwide communication, etc.);

- error likelihoods associated with various shipboard activities and the additional time needed for error recovery or prevention;
- impact of manning/personnel changes for time and reliability associated with shipboard activities (e.g, increasing CIWS loading crew from 3 to 4 men);
- cross-training implications on crew rotation;

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The DCA, as shipboard CBR-D advisor, might continue working with the DECAID system to arrive at a systematic set of recommendations/predictions for the CO. For example, if one evolution of a topside operation takes a three-man crew 20 minutes to perform at MOPP IV and the maximum watch length to keep the probability of heat stress casualty to 5% (or less) is 40 minutes, this implies that a single crew can be expected to perform, at most, two evolutions safely. If additional (sustained) operations are called for, then this crew must be relieved by a another crew which is trained or cross-trained to perform that same task. By introducing a fourth crew member to the three-man crew, DECAID might predict that a single evolution can be completed in 15 minutes at MOPP IV, which in turn leads to the probability of completing three evolutions within approximately 45 minutes; DECAID might predict that an additional 5 minutes of heavy manual labor increases the heat stress hazard exposure from 5% to 10%. And so on. This scenario, while purely a 'thought experiment', should be sufficient to suggest that the goal of a HPPS is to provide comprehensive and integrated human performance predictions within a framework of shipboard tactical operations.

CAVEATS ON DECISION AID MODELS AND DATA BASES

Some words of caution on human performance data bases and models are in order. First, specific models and data bases which might serve as modules for HPPS are not yet available. Relevant models and data bases have been created separately, but the need is great to adapt existing models to DECAID and develop new models and data bases which will serve HPPS requirements. Second, models are analogies about reality (Chapanis, 1961) and thus are often inexact. The required degree of precision a model gives to aid decision making is a function of the decision task being addressed. Third, data bases must be scrutinized for validity, reliability, timeliness, and completeness. Fourth, it should be noted that many aspects of human performance have not been quantitatively studied and modeled. Because of the many PSFs that can operate on a person, performance prediction can sometimes be very inexact. Fifth, models and simulations are always limited in the range of conditions they are acceptably predict or describe. Outside that certain boundary conditions, precision may fall off quite rapidly. Sixth, response time is a major consideration. The speed with which a decision aid (model or data base) can accept inputs and provide an output must be within the time constraints imposed by the decision task at hand. A stability calculation which provides a result in 20 minutes may not be acceptable if the damage situation is changing more rapidly than that. Despite these caveats, however, we believe that the types of models discussed here are a good basis for an HPPS facility within DECAID and hope that, over time, it may be designed, developed, implemented, expanded, and refined to eventually provide the degree of description, prediction, and control naval officers require to accomplish their objectives.

PHASED GROWTH OF DECAID DECISION AIDING CAPABILITY

Many concepts of use for DECAID in its decision aiding mode have been mentioned in this section. Potential applications have been discussed one at a time, though mention has been made of the desirability for interactive and integrated decision aiding modules which support the DCA in a comprehensive and integrated fashion. Because it is unlikely that the specific modules will be available all at once, the modules will probably be implemented into DECAID serially over time. Therefore, the need is great to integrate them into a coordinative architecture which allows different models and data bases to "talk" to one another before providing output to the DCA. This need includes the ability for different models to call upon a single data base. This includes the need for output from one model to serve as the input to another model. This includes the need to provide decision aiding output which can be both tailored to the decision maker's request as well as to provide output appropriately collated and displayed as a composite so as to foster an appreciation for the impact of the decision task on other related tasks. Part of this challenge is developing the technology to allow this integration to take place quickly and accurately. Another part of the challenge is to understand sufficiently the decision environment aboard a naval vessel under a wide range of circumstances and the psychology of command decision making in that environment.

As discussed so far, DECAID decision aiding is initially to be provided 'passively', i.e., in response to DCA/student requests for decision support. This puts the burden on the DCA/student to perform many decision making activities unaided or actively seek out decision aiding in response to specific problems. In the future, it may be possible for DECAID to provide 'active' decision aiding. Under this scheme, DECAID might provide onboard support by accepting a more or less continuous stream of sensor and human observer inputs about ship state. The system could then compare current ship state against a baseline description of 'normal' ship state and alert the DCA when some aspect of that description falls out of tolerance. In addition, this advanced decision aiding system would provide the guidance needed on the best approach to correct the situation. In principle, such a system could work autonomously (excepting, perhaps for repair crews to carry out its decisions), since the ultimate system would have all the expertise and tools needed to accurately and quickly assess the situation and arrive at a more favorable one. We recommend that the development of such a system be pursued. However, we have also alluded to some of the difficulties associated with achieving this goal. Therefore, we hold that it is best considered a long-range product improvement option rather than something which is to be built into the initial version of DECAID.

SECTION 8.0

EVALUATION STRATEGIES FOR DECAID

INTRODUCTION

DECAID is intended to serve as a desktop trainer and as a decision aid. How successful DECAID is in fulfilling these roles should be evaluated during each stage of its development so that by deployment it will have been shown to be effective. Unfortunately, literature reviews and discussions with content-area experts lead us to the conclusion that very little attention has been given to the evaluation of decision aids and even less attention has been devoted to the evaluation of decision training. Consequently, we can only draw on a few sources of information with respect to the evaluation of DECAID as a decision aid/trainer system.

A variety of approaches to evaluation may be considered. Trainers and decision aids can be evaluated in comparison with another trainer or decision aid, an alternative design concept for the same trainer or decision aid, with untrained or unaided performance, or with respect to some performance standard or design goal. The first three methods require at least a prototype of the trainer or design aid in order to perform the evaluation. While DECAID is in the concept development or design stage, only the fourth method is relevant, i.e., comparisons with performance standards or design goals. To further support this point, Riedel and Pitz (1986) generated a table in which they show types of evaluation questions for each stage of development for a decision aid (see Table 8-1). Note that during the prototype or operational stages the questions can be answered through inspections, tests, experiments, or demonstrations; in the design stage, the questions can only be answered through reviewing design concepts in light of specified goals, standards or guidelines.

DESIGN GOALS AND EVALUATION CRITERIA

Design goals for a computer-based decision aid or training system address three, overlapping areas. First, there are goals directed toward providing

Table 8-1

Life Cycle Evaluation for the Development of a Decision Aid
(Source: Reidel and Pitz, 1986)

Decision Aid Stage	Evaluation	Examples of Evaluation Questions
Design	Task	Is the decision algorithm capable of aiding the steps that need aiding?
	User	Does the interface design meet human factors design standards?
	Environment	Are the hardware specifications compatible with the organization's computer system?
Prototype	Task	Was the algorithm programmed correctly?
	User	Does the user think the aid helps him/her?
	Environment	Is the aid politically acceptable?
Operational Aid	Task	Does use of the aid speed the decision making process?
	User	Are the results of the aid used?
	Environment	Is the aid reliable in the operational environment?

a usable interface between the system and the user. Second, there are goals directed toward fulfilling the requirements of the tasks to which the aid or trainee will be put. Third, there are goals directed toward providing adequate 'fit' between the system and the environment (both organizational and physical) to which it is directed. Each of these three areas is discussed below.

System-user interface

The first area, user-system interface design goals, can be broken into those for the 'physical' interface and those for the 'dialogue' interface. The physical interface covers fundamental hardware features such as symbol size, display brightness and contrast, keyboard characteristics, position of controls, and the like. Standards documents such as MIL-STD-1472C serve as a ready source for design goals leading to an ergonomically sound physical interface. A checkoff list will often serve as a useful tool for evaluating the physical user-system interface (for review of design specifications initially and for conducting equipment inspections when appropriate). On the other hand, the dialogue interface covers the (software) communication link between user and system and includes user-to-system communication (i.e., the manner in which data/commands are entered into the system), as well as system-to-user communication (how system output is displayed, how system HELP is provided). Standards documents such at MIL-STD-1472C, guidelines documents such as Hamel and Clark (1986), and subject matter experts (e.g., SWOS instructors and DCAs) serve as important sources for design goals on the software interface Evaluation of the dialogue's ease of use is best made through early and frequent user-oriented tests which employ representatives of the potential user community (e.g., SWOS instructors, DCA students, DCAs aboard ships); storyboards and prototyping systems can also be helpful in this regard.

System - Task Interface

The second area of design goals addresses how the decision aid/trainer meets task requirements. The goal is that the device must train and/or aid the user in those duty areas for which decision making is a key element. The source of guidance for task requirements is a task inventory and task analysis. The task inventory would identify all (critical) DCA duties and tasks. The task analysis should identify, for critical tasks which involve decision making, what decisions are to be made, the information input needed, the decision strategy/algorithm necessary, output content and format, decision implementation, time/accuracy requirements, organizational (Navy/ship/training center) constraints, etc. If this information shapes DECAID's design, then it is, conceptually, complete; it should provide good decision aiding to DCAs and its trainees should exercise good decision making. From a practical point of view, however, it may be possible to specify only some of the above information; risk management decisions, for example, do not have a readily identifiable algorithm. Thus, the DECAID system should be considered, and evaluated, as an evolutionary system which will increase in capability over time as more comes to be known about the DCA's decision environment.

An underlying problem with evaluation in the task requirements domain is the fact that decision making (aided, trained, or both) often cannot be judged on the basis of outcomes alone. As we have discussed in previous sections of this report, decision making under uncertainty may be followed by favorable outcomes or unfavorable outcomes. (For example; Does the former indicate competent decision making while the latter indicates incompetence? The answer is 'it all depends'). Sound decision making might be followed by disaster because of inadequate resources to counter the threat (a no-win situation), miscommunication among subordinates, or the probabilistic and rapidly changing nature of the situation. On the other hand, poor decision making might be followed by a favorable outcome by chance alone. Therefore, it seems that a key element of any evaluation scheme for decision aids or decision training must of necessity focus on the 'process' used by the aid or the trainee rather than the 'product' since the product is a result of more than just the decision process alone. Riedel and Pitz (1986) make the good point that often it is difficult to identify what a good decision process is or how to measure it. They do acknowledge, however, that 'process' evaluations are most appropriate at the design and prototype stages. At this conceptual stage of DECAID development, we offer no ready answers to these issues but acknowledge that they are present and thorny and will have to be dealt with. For procedural decisions, it will be possible to evaluate if the trainee has mastered the associated facts and procedures. For risk management decisions, the evaluation criteria are much less clear. Initially, it may only be possible to describe risk management decision making rather than evaluate it.

Another use of the task analysis referred to above is for task allocation. After the task analysis is completed, a determination should be reached about which decision tasks should be trained, which should be aided, and which should be both trained and aided. In today's Navy, no such determination is available ... the DCA is expected to do everything. We have, though, proposed examples throughout this document where we think enhancements are possible. We have adopted the attitude that the existing training concept (i.e., comprehensive DCA training for unaided decision making) will continue for the foreseeable future. But we wish to introduce instructional delivery, scenario presentation, and decision aiding concepts which will increase the DCA's effectiveness both when automated assistance is available and even when it is not. Ultimately, official determinations of what will be allocated to the DCA and what will be allocated to decision aids will be both beneficial and necessary. In the future, it may be determined, for example, that stability and buoyancy calculations will be automated and only principles of stability and buoyancy will be taught.

System - Environment Interface

The third area and final area for design goals is how DECAID interfaces with the environment. This area covers the 'fit' between system and the physical environment into which it will be place. Design goals and evaluation criteria might consider requirements of space, power consumption, transportability to target computer hardware and operating systems, etc. This area also includes compatibility with the organizational environment into which DECAID will be put (e.g., SWOS schoolhouse application, ships for On Board Training(OBT) and aiding). Organizational goals and evaluation criteria at this level might encompass reliability/availability/maintainability, organizational impacts on the DCA course or OBT, personnel requirements, level of funding needed, time requirements and so forth.

Table 8-2, provided in Reidel and Pitz (1986), gives a useful summary of general decision aid evaluation criteria which might be appropriate to DECAID.

Note that this summary cuts across all three of the goal areas described above. Selection from among these criteria, as well as the development of additional criteria, will depend upon the specific goals of an evaluation, i.e,. what questions are to be answered, and by the constraints imposed on the evaluation process itself (time, available funding, human resources requirements, etc.).

Table 8-2

Summary of General Decision Aid Evaluation Criteria
(Source: Reidel and Pitz, 1986)

Appropriateness for the task	logical soundness
	decision process changes
	options generated - number
	- quality
	attributes generated - number
	- quality
	information used
	procedural changes
	precision
	flexibility
	implementation consistent with decision algorithm
	correct answer as measured by expert opinion
	ground truth
	rationale for decision
Appropriateness for the organizational user	political acceptability
	institutional constraints
	time requirements
	personnel required
Appropriateness for the end user	skill level needed
	effort level needed
	convenience of access
	adequacy of documentation stored above aid
	training and leadership
	learnability
	transfer
	retention
	errors - proneness
	- detection
	- recovery
	- criticality
Appropriateness for the end user	user acceptance
	attractiveness
	convenience
	confidence
	understandability
	of decision model
	of aid decision
	satisfaction with results
	ease of use
Appropriateness for the environment	implementability
	reliability
	security
	level of development
	expandability
	compatibility with existing systems
	level of funding needed
	hardware and software support needed
	fit of system with existing system

SECTION 9

DECAID FUNCTIONAL DESIGN DESCRIPTION

OVERVIEW

In response to guidance provided by the U.S. Navy, DECAID is targeted to be implemented using a microcomputer-based (desktop) system. This section describes a hardware/software configuration for such a system, which will possess the functional capabilities implied by the concepts of use presented previously in this report. This functional description can be used to guide detailed design in the future and may be modified to reflect specific concepts of use judged to be of greatest immediate value to the Navy.

In its first application, housed in a stand-alone Zenith Z-248 (See Figure 9-1) (IBM PC/AT-compatible computer). DECAID will support Damage Control Assistant training and decision aiding for CBR-D conditions. The DECAID system as described in this functional description will consist of instructional modules, CBR test scenarios, and selected decision aids, along with data analysis and administrative capabilities. DECAID instructional modules will provide computer-based instruction to develop basic CBR expertise and familiarity with decision-relevant concepts, data, and calculations. CBR test scenarios will provide a means for integrating basic expertise, concepts, data, and calculations into effective decision-making by providing scenarios that include realistic ship-plate graphics and simulated DCA functions. Decision aids will support the management of crew, time, and equipment resources to counter CBR and damage control threats.

DECAID has several modes of operation. Each mode has a specific interface and set of functions which DECAID can support. Table 9-1 below describes DECAID's intended flexibility as a training concept for each of its six (6) user-selectable modes.

The DECAID system will integrate microcomputer system hardware, software, and interfaces with applicable models, data bases, ship-plate graphics, and instructional software. The remainder of this section will further describe each of the elements in the DECAID system description depicted in Figure 9-2 at the conceptual level.

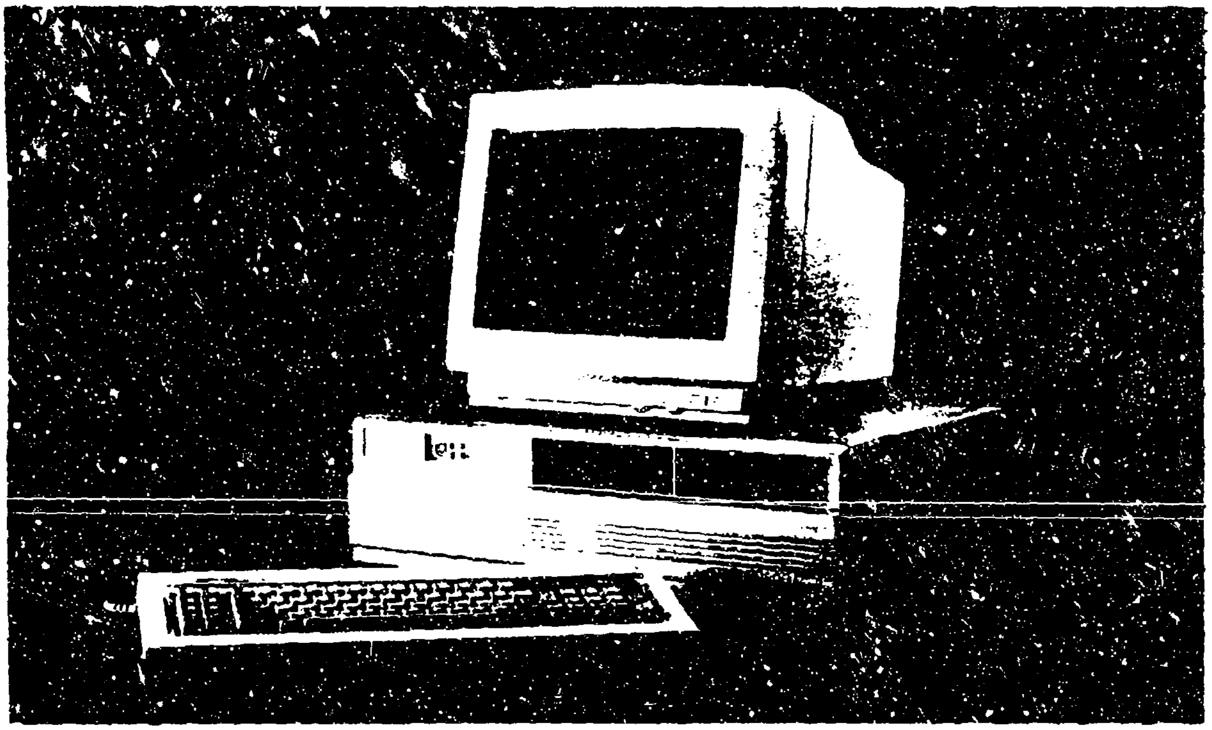

Figure 9-1. Zenith Z-248 micro-computer system.

DECAID Modes and Functions

MODE 1–SYSTEM CONFIGURATION SELECTOR –ESTABLISH SESSION DEVICES AND FUNCTIONS	MODE 2–INSTRUCTIONAL DELIVERY –CONTROL DCA TRAINING SESSION	MODE 3–SCENARIO/TEST DELIVERY –CONTROL SCENARIO EXECUTION	MODE 4–DECISION AIDING	MODE 5–TRAINING SYSTEM MODIFICATION –UTILITIES FOR EDITING CODE, GRAPHICS, DATA	MODE 6–TRAINING ADMINISTRATION –SCHEDULING, PERFORMANCE EVALUATION, REPORTING
MODE 1 INSTRUCTOR INTERFACE	**MODE 2 STUDENT INTERFACE**	**MODE 3 STUDENT INTERFACE**	**MODE 4 STUDENT INTERFACE**	**MODE 5 INSTRUCTOR INTERFACE**	**MODE 6 ADMINISTRATOR INTERFACE**
1 • Password access to system-level configuration selection menus • Menu options for - Scenario select/enable - Instructional system enable - Printer select - Network start-up - Actuarial data dump - System backup - Configure workstation functions	1 • Name identification and lesson selection • Lesson interrupt • Lesson review • Lesson resume • Quit	1 • Name identification and scenario log file notation • Certification of completion of prerequisite instruction • Overview of major topics to be tested • Commence scenario on student's command	1 Menu options for: • Human performance prediction • Stability and buoyancy calculation • Inventory control • Routing • Accessing databases • Other options	1 Menu options for: • Graphics Editor • Code Compiler/Linker • Code editor • Modular modification submenu • DBMS • Model default(s) editing	1 Menu options for: • Training scheduling • Maintenance logs • Performance evaluation routines (system and student) • Reports generation for SWOS CO and personnel records
MODE 1 INSTRUCTOR FUNCTIONS	**MODE 2 STUDENT FUNCTIONS**	**MODE 3 STUDENT FUNCTIONS**	**MODE 4 STUDENT FUNCTIONS**	**MODE 5 INSTRUCTOR FUNCTIONS**	**MODE 6 ADMINISTRATOR FUNCTIONS**
2 Instructor will be able to: • Enable Training System Options • Configure workstation • Prescribe "Master Chief" • Perform System Administration Functions • Start the Network Emulation • Obtain training data reports	2 Student will be able to: • Begin, end, interrupt, resume, or review an instructional module • Print screens and result files • Access DECAID Help files	2 Student will be able to: • Initiate scenario/test • Certify completion of prerequisites • Obtain overview of major test topics - Call Master Chief Help/Rules/etc - Make decisions/specify courses of action 'Obtain optional information on completeness/correctness of decisions or possible courses of action - Query lessons learned data base	2 Student will be able to: • Enlist computation support • Obtain data table look-ups • Check inventory status • Determine optimal routings • Predict outcomes of decisions - Call Master Chief Help/Rules/etc - Make decisions/specify courses of action - Obtain optional information on completeness/correctness of decisions or possible courses of action - Query lessons learned data base	2 Instructor will be able to: • Modify files, graphics, scenarios, etc • Change model default input files • Access and change databases and load/update data files	2 Administrator will be able to • Schedule system use • Keep training and system records • Make comparative performance assessments • Obtain reports of student performance, system utilization, response time, etc

Table 9-1. DECAID modes and functions

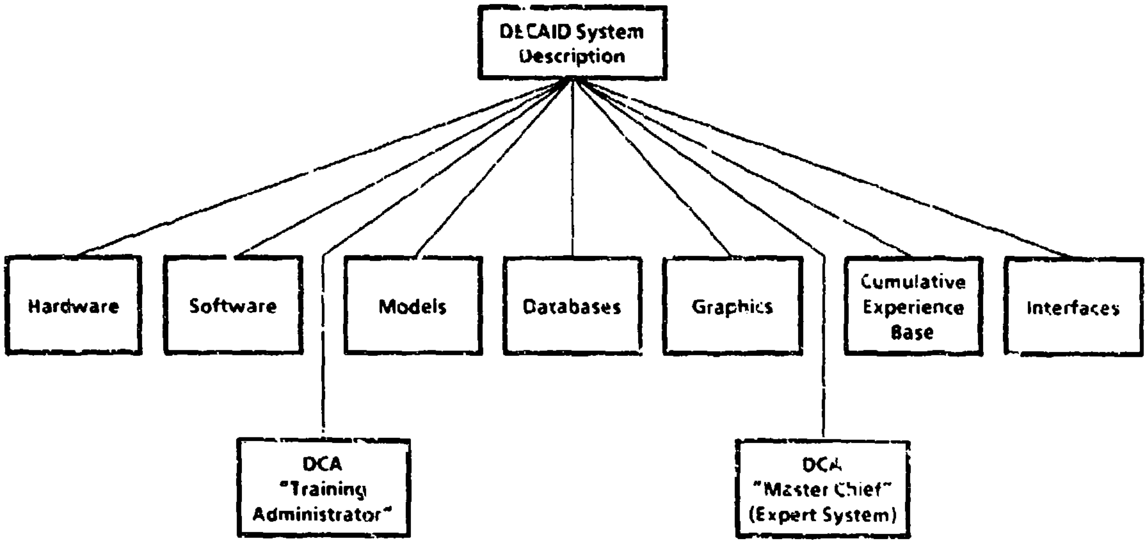

Figure 9-2. DECAID system description.

HARDWARE

The standard microcomputer system proposed as DECAID training device host is the Zenith Data Systems model ZWX-248-52, or simply Z-248. This microcomputer, authorized by the U.S. Government Services Administration (GSA), was specified by NTSC for DECAID to assure compatibility with existing microcomputer systems. Conceivably, DECAID could be integrated with other computer training systems through a local area network in order to provide the greatest degree of flexibility, information transfer and storage capability. Initially however, it is expected that the Z-248 will operate in a stand-alone configuration. The network option should be considered as the number of DECAID training workstations and data requirements grow.

Figure 9-3 gives a breakdown of DECAID hardware, including salient aspects of the Z-248 and an optional local area network.

Stand-Alone Z-248 Microcomputer

It is anticipated that DECAID will be implemented on Z-248 PCs to be used as training workstations that operate independently. Each workstation would store certain graphic data in ROM chips and on its hard disk. The training/simulation programs would also be stored on the hard disk. Some advantages of the stand-alone configuration follow:

- Interim result/scenario files could be copied to a floppy disk allowing interruptions to training, to be resumed later on the same or different workstation.
- Training could continue on an adjacent system if equipment failed--to provide graceful degradation.
- System response speed would be maximized at each workstation, and would not vary with an increase in the number of DECAID users.

Since the Z-248 is an IBM compatible microcomputer, optional hardware includes the whole host of IBM compatible peripherals, aftermarket products, and system upgrades. DECAID system upgrades might add hardware such as:

- input/output (I/O) devices (e.g., graphics tablet, cursor mouse, light pen, or touch screen)
- storage devices (e.g., optical disks, streaming tape, removable hard disks, and additional memory cards).

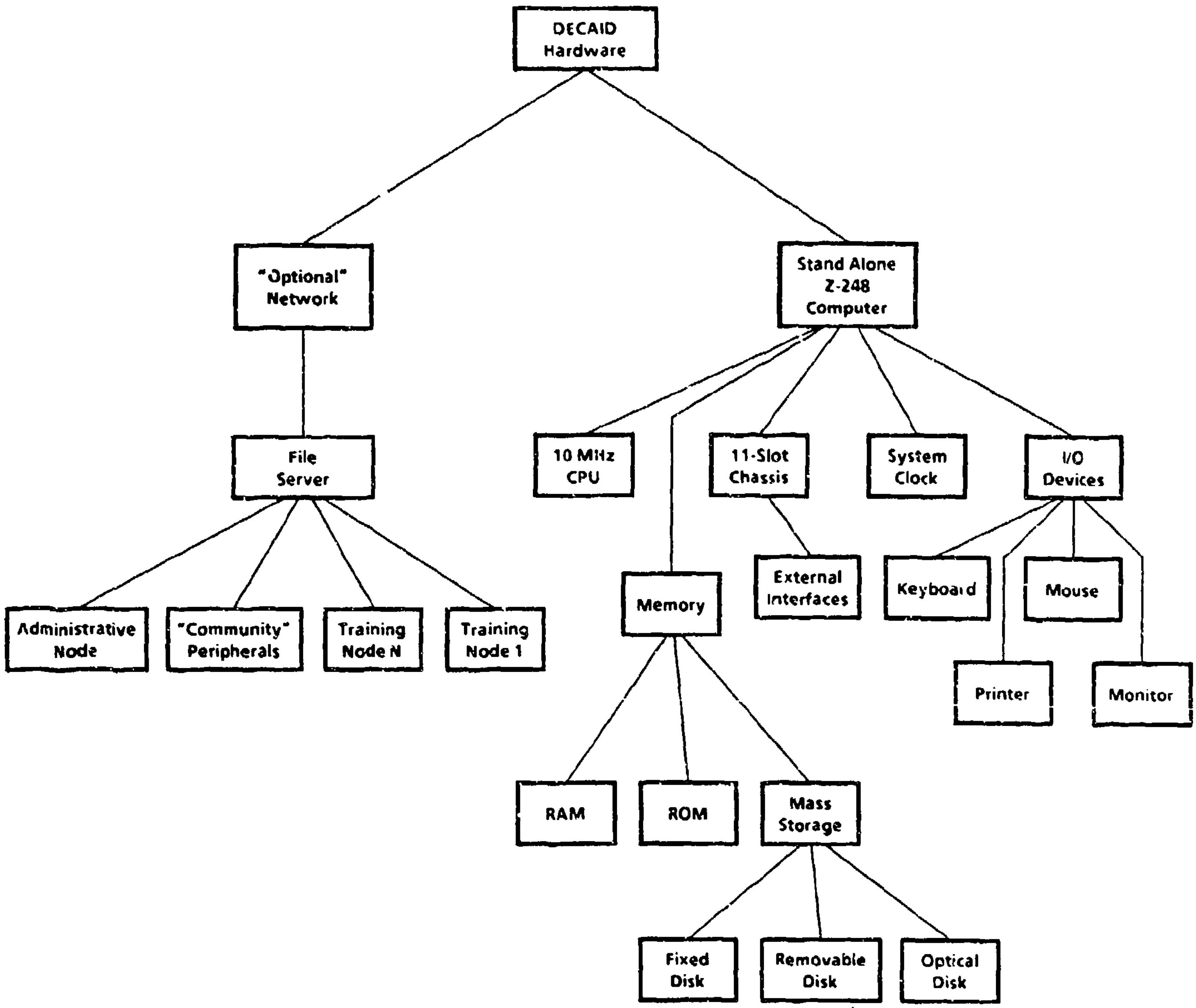

Figure 9-3. DECAID hardware structure.

CPU Specifications

The Z-248 computer is configured as depicted in the DECAID (Z-248) System Block Diagram (Figure 9-4). In its GSA-standard configuration, the Z-248 has the following hardware attributes:

1.	Processor	Intel 16 bit, 68-pin 80286, 8 MHz, 0 wait state. Optional 80287 math coprocessor.
2.	Initialization	Refresh and any other controller in an expansion slot with an initialization ROM will be initialized during the self-test sequence. If equipment fails to operate correctly, then error messages are displayed. An alternative would be to add an Optical Disc capability for storage of graphical files (ship plates, etc.). This alternative would not require the additional ROM cards and would allow <u>all</u> necessary graphics to be prestored.
3.	Disk Drives	Single 5.25" 360kB double sided/double density floppy disk drive; 20 MB, 80 ms access time Winchester (or equivalent) drive. The Z-248 can support drive two hard disks and two floppy disk drives.
4.	Disk Controller	Combined Winchester and floppy controller supports 2-360K 5.25" or 2 1.2 MB 5.25" drives plus two Winchester drives.
5.	Expansion Capability	CPU has 10 bus slots, six open for expansion, including one 8-bit PC compatible, and five 8/16 bit PC/AT compatible expansion slots. (Note: The Z-248 expansion capability has important implications for the presentation of computer graphics. Data transfer from ROM is about 10 times faster than from a fixed disk and screen paint times from ROM are faster, too. The Z-248 supports six expansion slots that could house permanent graphic data on cards with 25 EPROM chips apiece (i.e., 1.6 MB of graphic file storage). Additional cards would support ROM to be used for graphic boilerplate (e.g., ship plates). Present graphic technology for IBM-compatible PCs provides for 640 X 480 pixels in 16 colors. Thus, four ROM graphics cards could store approximately 40 fixed graphic images.)
6.	Weight	38 lbs (17.2 Kg).

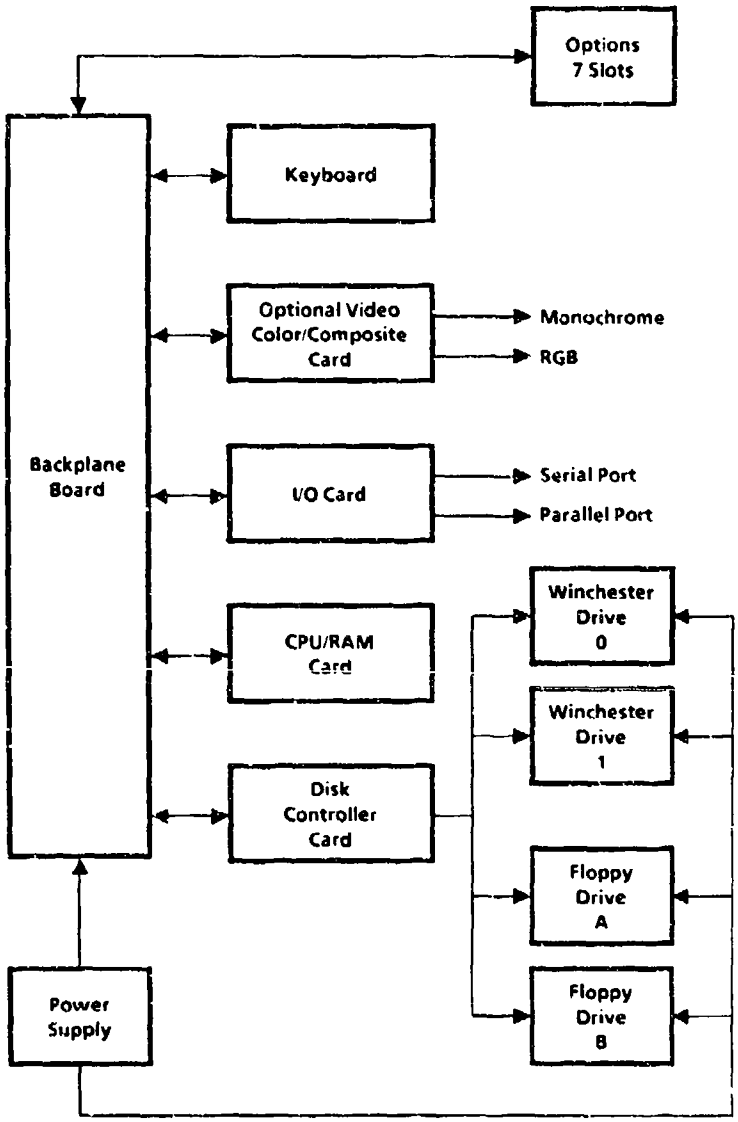

Figure 9-4. DECAID (Z-248) system block diagram.

7.	Size	21W X 16.5D X 6.5H in (53.3 X 41.9 X 16.5 cm).		
8.	Environmental Limitations	a.	Temperature (NOTE: The ruggedized version may have a wider temperature range (i.e., -20 to +50°C)	50-90°F
		b.	Humidity	20-80% RH
		c.	Power Requirement	105-125V at 50/60 Hz at 200W
9.	Power Supply	a.	Input Voltage	115 VAC ±15V
		b.	Line Frequency	50 Hz or 60 Hz ±3 Hz
		c.	Input Line Current	4 A maximum continuous
		d.	Output power	200 W maximum

Has brackets for additional floppy drives and another Winchester hard drive.

System Clock(s)

The Z-248 comes with one continuous running real time clock with a Lithium battery. The clock frequency is 8 MHz. The clock provides a time-of-day and alarm, and a calendar spanning 100 years. Other real time clocks could be added as required to support DECAID software.

System Memory

The Z-248 computer comes equipped with standard Zenith Read-Only-Memory (ROM), Random-Access-Memory (RAM), and mass storage memory in hard and floppy disks, described above.

The standard RAM is 512Kbytes. It is expandable in 1.5 MB blocks up to 3.5 MB using an add-on Z-445 memory card (on minimum required RAM should be 2.0 Mbytes).

The Z-248 is equipped with 128Kbytes of ROM which includes a MONITOR program, preset at the factory to load (boot) DOS. It can be disabled using the ROM-based CTRL-ALT-INS SETUP program.

Selected EPROMs located on the CPU card store contain the MONITOR program which is activated by CTRL-ALT-INS. Two additional 64K EPROM slots are available on the CPU card for other low-level programs.

I/O Devices

The Z-248 comes with an optional EGA video card as configured per GSA schedule. IBM compatible video cards, including the new VGA analog video capability, are also available as optional add-ons. It is expected that EGA will be adequate to support DECAID displays, initially.

1. Video

Enhanced Graphics Adapter (EGA) standard (IBM compatible, can display 16 colors of a 64 color palette in 640 X 350 pixel resolution (8 X 14 character cell); it is an alternate CGA-compatible 640 X 200 mode (8 X 8 character cell). Refresh rates are 60 Hz and 50 Hz, respectively.

The default cursor is a blinking underline or reverse video block.

2. Optional Video

Compatible cards range from IBM Monochrome Display Adapter to Compaq Video Graphics Controller Board (VGA) graphics. Many other graphics cards can be used, too. VGA performance is the best available in PC graphics. VGA is capable of 640 X 480 resolution with 16 colors of a 256,000 color palette at 70 Hz refresh rate.

It is anticipated that DECAID will use the ZCM-1490 Flat Technology 14" (diagonal) color monitor, or equivalent. The ZCM-1490 supports EGA, VGA, CGA, and MDA/Hercules. Contrast is improved 70% over conventional CRT displays. The monitor accepts an analog input signal of 0 - .714V. It operates at either 110 or 220VAC. Dot pitch is .28mm. Dimensions are 12.25H X 14.75 W X 15.50 D in. The ZCM-1490 operates at 60-70 Hz vertical refresh and 31.49kHz horizontal scan. It weighs 40 lbs. and includes a swivel/tilt base.

3. Keyboard

The Zenith standard keyboard contains 84 keys laid out in three major groups. The central portion is standard QWERTY typewriter layout; the left side has a 2 X 5 block of 10 function keys which can be user defined; the right side has a 16-key keypad, the keys of which are software-defined and contain legends for numeric entry, cursor control, and calculator pad screen editing. The Z-248 keyboard is similar to the IBM PC/AT -style keyboard depicted in Figure 9-5.

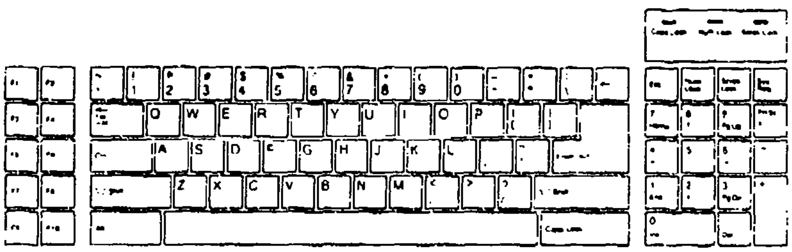

Figure 9-5. DECAID (Z-248) standard keyboard.

4. Input/Output Card — This card includes:

Serial port	-	serial communication through a 9-pin "D" type connector
Parallel port	-	parallel communication through a 25-pin "D" type connector
Keyboard interface	-	bidirectional communication through a 5-pin DIN connector on the backplane; processed by a system control processor on the I/O card
Real-time clock	-	provides a time-of-day clock with an alarm, and a 100-year calendar
Interrupt Controllers	-	Two cascaded 8259 programmable interrupt controllers prioritize interrupt requests from as many as 15 different devices
DMA Controllers	-	Two cascaded 8237A-5 DMA controllers to process 8-bit or 16-bit DMA data transfers

Optional Microcomputer Network

As part of a preplanned product improvement program for long range DECAID development, one ought to consider a network of Z-248 computers to support several training workstations. A potential network configuration including instructor and student workstations, and in interface with another training system is shown in Figure 9-6. The potential benefits of networking are presented below.

There are several training-related benefits which networking might offer. First, an instructor at his own station would be able to unobtrusively monitor student performance. The instructor might also be able to intervene during a scenario or instructional module, again unobtrusively. Second, several students might be able to observe the same DECAID problem at separate work stations; students might also be able to work as a damage control "team", each playing a different role. Third, it is possible for an instructor or student at one workstation to serve as an adversary for another student, thus giving the latter exposure to the challenge of a "diabolical" threat.

Although the network would increase initial system cost and maintenance

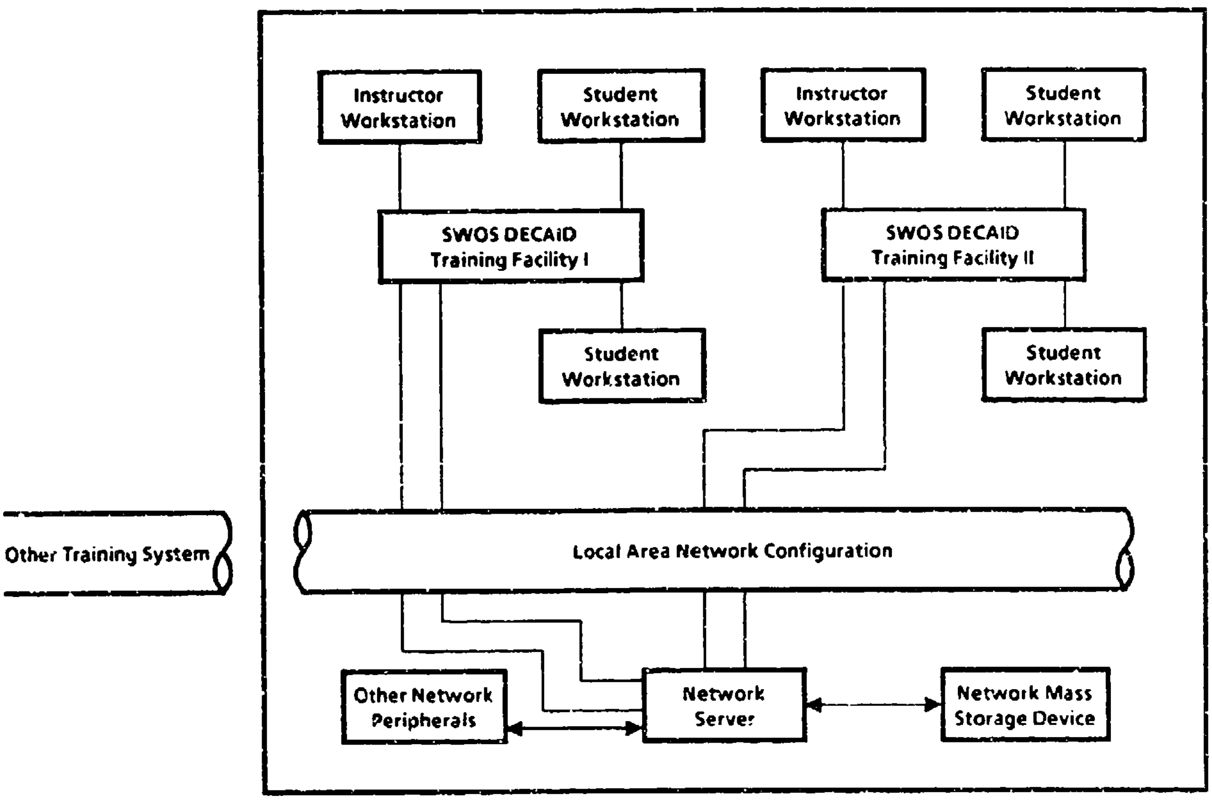

Figure 9-6. DECAID instructional workstation network configuration.

logistic burdens, there are several major logistical advantages for the Navy training facility using DECAID as well.

- Networks enable a group of computers to share peripherals, such as printers and mass storage devices. The potential growth and increasing complexity of DECAID scenarios could dictate the need for greater storage and processing speed to attain desired simulation performance and system response times. A network file server could drive a large-capacity mass storage device from which individual workstations could download selected scenario files. This could effectively speed up system performance at the individual workstation.

- DECAID training system software updates might be simpler to implement on a single network server than could be expected on several machines.

- Unique applications could be stored at each workstation, since the network server would house the large data bases, models, and data files.

- Other computer training systems could share information with DECAID.

There are basically two networking options. The first option is a circular design (or token ring) where the networked workstations take part in "passing a token" around the ring. (A 'token' is a software entity which causes control of the net to transfer to the designated processor). The second option is a straight line, ethernet, network where the networked workstations ignore information packets directed to other workstations. Like the stand alone configuration, both of these configurations require each workstation to have significant processing capability, since the network server would "download" the simulation program and subsets of data base information for local processing at each computer workstation.

File Server. File servers are large, high-speed microcomputers. Presently, most network companies recommend IBM PC/AT (80286-based) machines at a minimum. The powerful, new 80386 machines typically have a speed and storage capacity advantage over the less expensive 80286 computers. The cost of 80386 machines can be justified if a number of workstations tie in--the server cost per workstation on a ten-workstation network would only be a few hundred dollars, at most.

Peripherals. Availability of shared peripherals such as plotters, printers, and special mass-storage devices and increased storage capacity is the hallmark of the local area network. Further, networks can tie otherwise incompatible computers together (i.e., microcomputers can share information with mainframes). The system security, growth potential, speed, and storage capacity typically available on a local area network using selected peripherals are also frequently cited as reasons for implementing a network.

Administrative Node. A network administrative node (a combination of particular equipment/passwords) provides a capability to control access, privileges, and to observe system usage characteristics. Software and data base updates, as well as other administrative functions would be handled by the administrator.

Training Nodes. Training workstation nodes would provide the controlled user-computer interface to each student. These nodes would have selected resident software necessary to start the network, but would also be able to download programs and data from the network server.

Hardware Logistic Requirements

The proposed Z-248 microcomputer system provides a reliable and inexpensive vehicle for DECAID. Hardware maintenance and repair should be no problem for DECAID since the Z-248 is IBM PC-compatible--there are many manufacturers of suitable replacement components. Most repairs can be accomplished within a few hours at any of the nation's Heath-Zenith Computer centers, or at other shops. Most repairs could be handled by using spare boards and swapping them out at a central repair facility or troubleshooting by experienced Navy electronics specialists using local tools and materials.

Maintenance Concept. DECAID hardware maintenance will be simple. Failed components will be taken to Heath-Zenith Computer or other retail computer outlets for repair or replacement. Other system aspects, including software, will be maintained by the DECAID system developer. Swapping at Heath-Zenith is not feasible in a shipboard environment. The spares would have to be purchased to support these machines -- especially if they truly serve a tactical role onboard ship.

Configuration Management. DECAID component configuration will be planned and documented by the DECAID system developer. Configuration changes are not expected until such time as new peripherals (e.g., optical disks, plotters, etc.) are added to the system. When new hardware is acquired, the supporting contractor will modify and document the system configuration, in collaboration with cognizant Navy personnel and Navy regulations regarding sparing, repair, configuration management software control, and other ILS/Acquisition policies.

Preplanned Product Improvement and Acquisition Plan. Microcomputer technology continues to advance and it is certain that the Z-248 system and its derivatives will be designed for faster handling of greater amounts of data and ever improved data display. For example, the new IBM analog video capability, the video graphics array (VGA), will become standard on new PC models. The new IBM operating system, OS/2, may also provide true multitasking on the microcomputer. It is quite likely that DECAID will benefit from the judicious addition of such new technology hardware and software.

The DECAID system developer should develop a preplanned product improvement and acquisition plan to incorporate these new technologies into the DECAID system. This involves the development of an acquisition strategy which would allow for both hardware and software upgrades.

SOFTWARE

Figure 9-7 presents a conceptual overview of the proposed DECAID software environment. In addition, this figure also depicts the roles and activities of both the instructor and the DCA student as they interface with this proposed environment. The majority of the software is intended to be implemented using currently commercially available "off-the-shelf" software. Those software elements which have to be developed are primarily related to data handling (file management and translation) and integration, and will be developed and coded using a high level language that is compatible with other Zenith system software.

Figure 9-8 presents the DECAID top level program design diagram. DECAID software will be subdivided into two environments, the computer system software environment, and the application-specific software environment. The computer system software includes the Z-248 operating system, utilities, and interface drivers, as well as off-the-shelf software packages that are appropriate for DECAID. Application-specific software includes the custom software which drives DECAID scenarios, instructional modules, and decision aiding function.

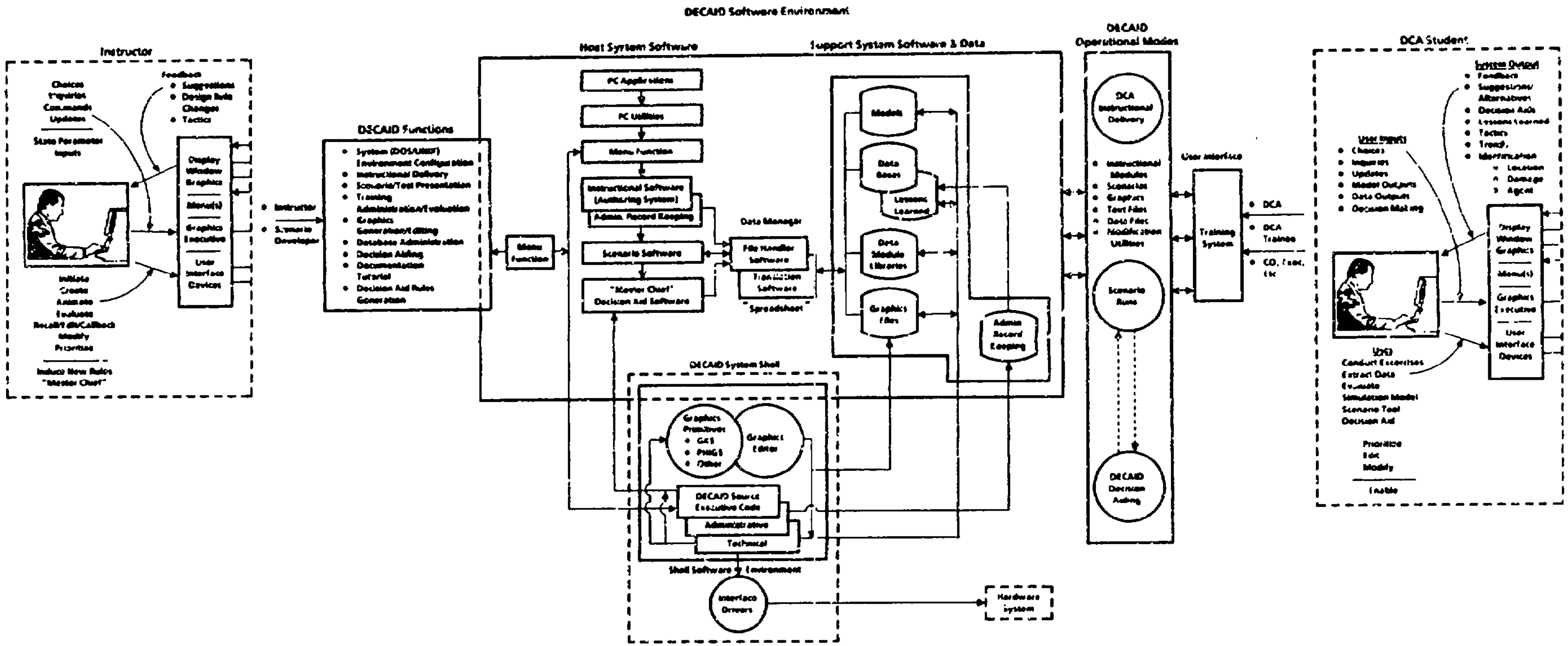

Figure 9-7. DECAID software environment and user interfaces.

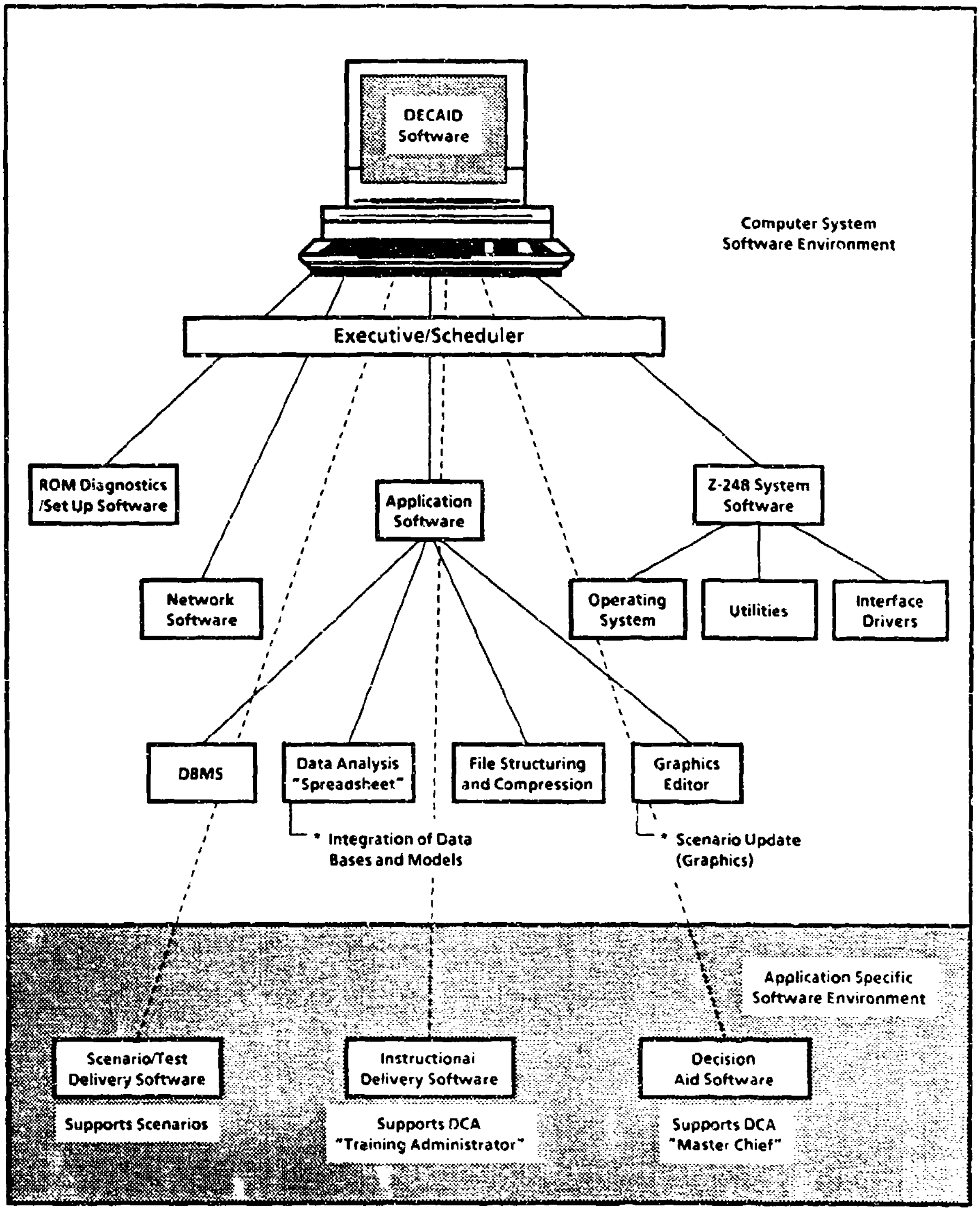

Figure 9-8. DECAID top level program design structure.

With this as a reference, we describe the Zenith Z-248 standard and alternative operating systems, the DECAID data base and software system integration and compatibility requirements, and DECAID system computational requirements. This information is based on the current inventory and state-of-the-art in microcomputer data bases, operating systems, and software, and is therefore subject to future revision when new products appropriate for the DECAID application become available. Details of Figures 9-7 and 9-8 are discussed in the remainder of Section 9.

System Software

Z-248 system software includes the MS-DOS 3.27 operating system, selected file handling utilities, and input/output (I/O) interface drivers. Most of these functions will operate invisible to DECAID's users, but may play a role in system installation, programming, and fault isolation activities. The important aspects of the Z-248 system software are described below.

Operating System. The Zenith Z-248 microcomputer officially supports Microsoft MS-DOS 3.27 and Microsoft XENIX; it could also support IBM's OS/2.

Per GSA contract, the Zenith Z-248 microcomputer is supplied with Microsoft Corporation's Disk Operating System, or MS-DOS, version 3.27. This disk operating system (DOS) provides certain low-level functions, invisible to the user, in the Basic Input/Output System (BIOS), which is maintained jointly in Read Only Memory (ROM) and in the operating system Random Access Memory (RAM). The DOS also provides user system commands for performing file control functions such as file listing, deletion, copying, editing, and batch processing; system configuration, including number, type, and format of mass storage devices and other peripherals; and other higher order processes such as filtering, piping, and port configuration.

The low-level BIOS provides standard interrupt ports that application programs use to control system hardware through memory registers. However, the BIOS can be bypassed, allowing memory registers to be directly affected by low-level assembler code. Bypassing the BIOS may or may not be necessary though, depending on the intent of and techniques employed in the application programs to be used. Since the BIOS helps to standardize hardware control protocols across microcomputer types, bypassing the BIOS would create software compatibility problems where different microcomputers run the same application program. It is expected that the DECAID software programs will use the Z-248 MS-DOS BIOS for addressing memory and port interrupts.

An operating system also controls the partitioning, or allocation, of RAM among the BIOS, the resident portions of the operating system, any virtual devices (RAM disks) and extended memory. The MS-DOS partition allows up to 640 kilobytes (K) of RAM for resident DOS and application programs. Additional RAM (beyond the 640K barrier) installed in a computer is only available for data manipulation and storage, but cannot support program execution.

DOS is only one of three primary operating system options available. It supports "simulated" multitasking (e.g., WINDOWS), but actually only allows sequential processing. Data base and program sizes are primary considerations for selecting DOS, since it only permits 30 MB of hard disk data storage and 640K RAM for the executable program. Thus, if a data base is larger than 30MB, a program is larger than 640K, or true multitasking is desired, then a different operating system is necessary.

Other operating systems constrain memory and mass storage only to hardware maximum limits. UNIX (XENIX), a multi-user operating system, supports true multitasking and has no unique memory or storage maxima. UNIX is used primarily in network and host time-sharing environments where one central processor houses mass storage and computational capabilities for several workstations.

The latest IBM operating system, OS/2, is continuing to evolve. OS/2 supports multitasking and also does not have unique memory or storage maxima. IBM released a Standard Edition in late CY 1987, which will be followed by an Extended Edition later in CY 1988. OS/2 requires a minimum of 2 MB RAM which supports its multitasking capability. Although current OS/2 graphics support is no better than that provided by DOS, IBM has promised a superior graphics interface in its mature OS/2 version, the OS/2 Graphics Presentation Manager, to be released in 1989.

Any of the above operating systems can be used on a microcomputer, but there are some points worth considering. One important point about operating systems is their mutual incompatibility. In other words, a program written to run under DOS cannot run under XENIX or OS/2. Although an application program written in DOS will not run in XENIX or in OS/2 directly, XENIX and OS/2 can provide a DOS "shell," a memory partition running DOS as a subset of the primary operating system. The DOS "shell" has all of the aforementioned operating limitations of DOS. Using the "shell" provides an advantage in that program applications written to run under DOS can be used on a XENIX or OS/2 machine. Any ASCII format data files such DOS programs generate could then be used by another application under OS/2 or XENIX.

Another significant point is that application products for DOS and XENIX are fairly abundant, while programming for OS/2 has barely begun. It may prove difficult to develop a suitable application program in OS/2, since the few existing OS/2 applications and utilities may be insufficient for DECAID programming requirements.

Conversely, OS/2 or XENIX may be necessary if DECAID data processing requirements exceed DOS working memory and storage limitations. This could become a particularly important point if a network is implemented for DECAID training workstations. Further study to forecast DECAID data processing requirements, and careful attention to XENIX and OS/2 state-of-the-art utilities are certainly warranted.

Utilities. The MS-DOS operating system provides certain file utilities and system files which can improve system performance and make DECAID an "automatic" training device. For example, batch files and system configuration files can access DOS utilities that allocate memory space, define keyboard functions, and system processing speed. Many DOS utilities provide a means for command-level interaction with the Z-248, and would not necessarily be used in the DECAID application.

Interface Drivers. Special software used to initialize and assign port interrupts for system interfaces will be required. For example, the use of a touch screen or mouse will require interface software of this sort. (NOTE: The device driver software is normally provided with the device since it is device peculiar).

Diagnostic/Configuration Program. In addition to the DOS utilities and interface drivers, the Z-248 system has built in diagnostic and configuration software programs that load from preprogrammed read-only memory (ROM). The diagnostic software provides system self tests on powerup to detect memory (chip) failure or disk errors. It also establishes the system configuration and initializes certain crystal frequencies, interrupt controllers, direct memory access (DMA) controllers, disk drive controllers, disk drives (if enabled in set up), as well as the CPU, ROM, RAM, video, keyboard, DMA interrupt, and disk controllers.

Application Software. Several application software "modules" provide data base management, data analysis, and graphic production functions to the DECAID instructional software.

DBMS. The data base management system (DBMS) provides DECAID with a means for quickly accessing important tabular information. This information provides input to the instructional software and scenarios to generate mission information, and is displayed to the student DCA when requested, and as appropriate.

For example, task completion data that are stored in the DBMS may drive both a model of human performance in MOPP gear and a DECAID display showing performance times juxtaposed with safe stay times for a given nuclear contamination situation.

Data Analysis "Spreadsheet" (Data Manager). The "Spreadsheet" is a function of the Data Manager Software and is a temporary data store for integration of data base records and various pre-stored models' outputs. In fact, this spreadsheet could provide an avenue for using data base records as the input parameter values to be processed in one or more of the models. The spreadsheet will operate behind the scenes, invisible to the DCA student and instructor. It will provide a means for translating data into proper input and display format, and will help speed up system response by providing a temporary data store for interim calculations. The resultant output will be a sequential file of data to be used as input (or interim results) for use by the student, instructor, or by the DCA in a real or simulated situation.

File Structuring and Compression. The large sizes typical of the many data bases, models, graphics files, and software residing on DECAID and the limitations of the operating system and mass storage devices require that file structures and storage routines be highly efficient. Special software will be required to provide efficient structuring and compression for storage. This software must be both reliable and quick however; otherwise system performance will be unacceptably degraded.

Graphics Editor. The graphics editor will provide a means for updating and modifying selected graphics files. Access to the editor will be limited to selected supervisory personnel and administrative staff. The editor will allow graphics to be modified to reflect actual ship configurations as they appear in update ship plates. The editor could also provide a vehicle for strategizing and for ship compartment reconfiguration.

File Handling Routines. The system will be designed and developed so that there are distinct interfaces between the individual modules that make up the user interface, data bases, and analysis (models) routines. Each interface will be thoroughly defined as to the type of information that will be passed, the format of the data, and the source of the data. A series of file handling routines will then be developed to handle the data interchange at each of these interfaces. These file handling routines will be in the form of "callable" subprograms that can be called from within a program as subroutines. Each subroutine will act as a primitive in that it will perform only one function such as opening a file, accessing a screen, or accessing a particular data base. The routines will be set up in a library that is accessible to the entire system.

User Interface. The user interface file handling routines will process information requests from the user or instructor. The user interface will be developed as a menu-driven or direct manipulation system and specific routines will be developed that will control the information flow to and from the screens.

Data base. The data base file handling routines will process requests for data and will consist of subroutines that will interface directly to the data bases. They will be written in the language of the data base management system.

Analysis (Models). The analysis file handling routines will process requests for execution of the models that perform the analysis. They will interact with both the user to obtain information and the data bases to obtain the required data. This will include interface routines for graphics.

The user shall be provided the capability to perform the following file handling functions:

a. Create
b. Update/modify
c. Merge
d. Delete
e. Read and link a sequence of files developed by other users to define a particular information display, a complete mission display set, or a training simulation.
f. Other functions to be determined by the DECAID detailed design specification.

Network Software (Optional)

A local area network (LAN) would provide DECAID training with the unique advantage of centralized, mass storage and shared access to system peripherals such as optical disks and plotters. Special software is required both locally (at each workstation) and at the site of the network server to control and coordinate communications, file storage/retrieval, and other network actions.

Host Server/Administrative Software. The host server software will be largely administrative. However, large datafiles and programs may appropriately be stored and accessed from the server. System log files and performance characteristic information could be included in the server software.

Node Control Software. Special software is required to control access and security on the network. Each node should have access to the "login" file, which should determine the level of access granted each node. Ideally, any function would be available from any workstation on the network; the function obtained would be determined by the privileges programmed for each user's name and system password.

Scenario/Test Delivery Software

DECAID will have a suite of software modules which drive the DCA test scenarios. The scenarios, to be developed under a later phase of this program, will have common elements which can be accessed through the core software program. For example, function calls to display ship plate graphics would be a part of the scenario software, since all scenarios would require that function. A plot of chemical cloud density might only be required on a few limited scenarios, so software driving that function might actually be contained as a part of the particular scenario itself. All software will be mutually compatible, and will have the capability to be appended together to add complexity/length to a given scenario test problem.

Instructional Delivery Software

DECAID instructional delivery software consists of programming that provides the DCA student with the conceptual information and rules necessary to appropriately respond to scenario stimuli. Introductory sections will explain the DECAID concept, discuss CBR-D tactics, and help acquaint the student with the user-computer interface, including available displays, command dialogue, information selection, data entry, etc. The "Training Administrator" module of the instructional software, discussed in detail later, will help keep records and provide performance feedback information to the DCA.

Decision Aid Software

Decision aiding software will consist of automated routines for superimposing important graphics and other information. The degree of involvement of the "DCA Master Chief" subfunction will be controlled by this decision aid software.

MODELS

The motivation for including a workable set of models and data bases applicable to CBR-D for DECAID is that DECAID is intended to support both training and decision aiding. In the training area, DECAID is oriented toward providing the student with simulated experience in making tactical decisions under the added burden of CBR defensive posture. Unless viable predictive models and data bases are available, such simulated experience cannot be provided with much hope of positive transfer of training. Models provide data that can drive realistic training scenarios and instruction which make DECAID a valuable training tool.

Models also form a core component of DECAID's decision aiding subfunctions. Models can provide the description, prediction, and control needed under conditions of CBR defense. Model outputs, then, can be used by the DCA (or others) to effectively make decisions about time, personnel, equipment, and threat management.

What is envisioned for DECAID is a library of models which serve various functions. A decision aid 'shell' would handle the entry of situation-specific data from the user (student or DCA). It would sequence the running of individual models, facilitate retrieval of data from a data base needed by the model (or models), and coordinate the phasing of models so that one model's output might become another model's input if required. The output of the models would then be formatted by the shell in such as fashion as to maximize the user's appreciation of the shipwide impact any given prediction has.

Previous sections of this report have suggested various types of models which might be included in DECAID to support training and/or decision aiding. In the area of human performance prediction, Figure 9-9 provides a picture of the kinds of models (and data bases) which will be required for HPPS. (The exact function and form of models needed for HPPS is to be determined through the detailed design specification). Within this framework, SOURCE models (and data bases) would describe the physics of different CBR agents. They might furthermore predict initial concentrations of agents and concentrations over time given the effects of air flow about the ship, location of a projectile hit, distribution of agent on a ship, whether the water washdown (WWD) system is operating, and so forth. Finally, environmental models might mimic realistic sets of weather indications for particular locales and seasons in terms such as wind direction and speed, ambient temperature, radiant temperature, percentage of overcast skies, relative humidity, etc.

PATH models would describe what happens over the course between contamination and crew. A ventilation model, for example, would describe agent concentrations in different compartments given flow rates, direction of flow, material condition, air volumes per compartment, and so on. Radiation shielding models could provide an indication of the protection (or, conversely, the transmission factor), afforded by decks and hull, distance to a radiation source, type of radiation, radiation contamination level, and half-life of a contaminant.

The RECEIVER part of DECAID's HPPS captures the impact of source stressors and path factors on human performance at specific tasks. To accomplish this, task analytic models and data bases would be needed to characterize the work that crew members are pursuing. Completion time models would predict thespeed with which such activities could be completed, given other factors. Accuracy

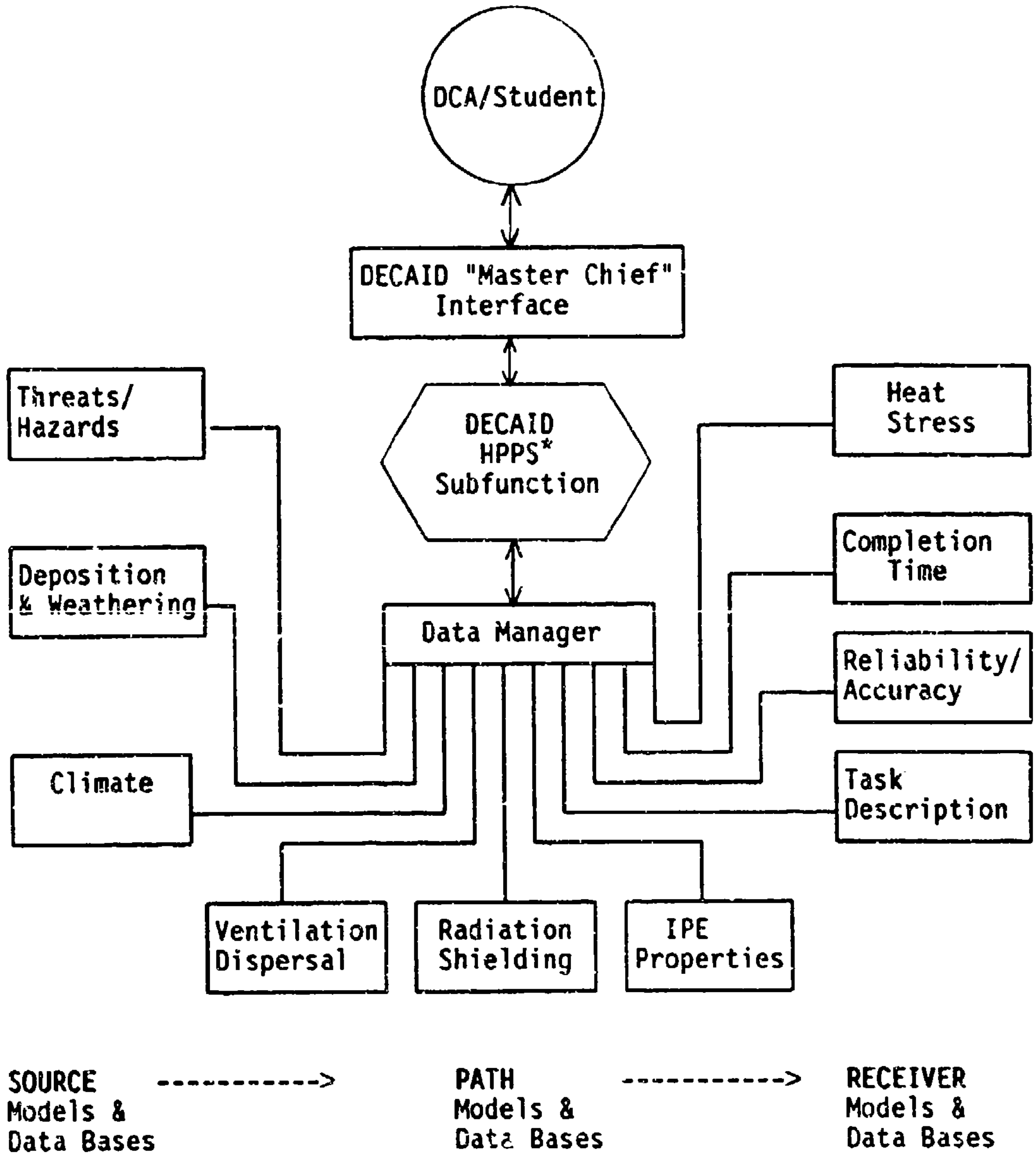

Figure 9-9. DECAID human performance prediction system source-path-receiver model.

models would likewise describe or predict the reliability w h which crew members might be expected to perform their duties. Heat stress models might be used to predict attrition rates, endurance limits, or watch lengths.

In principle, there are a variety of existing models and software tools which are relevant to DECAID; examples of some of these models are indicated in Table 9-2. Note well that this listing does not imply any endorsement of these models or any conviction that they are 'exactly' what is required. For instance, it is not yet clear how extensively they would have to be revised to be compatible with DECAID's needs and hardware/software architecture. Further examination of them (and other models) will be required during a detailed design phase to determine which available models may be used outright, which might be used after modification, and which must be developed specifically for DECAID application. However, available models such as those in Table 9-2 do indicate that many of the topics which are pertinent to the DECAID system development effort have been addressed previously. This suggests that there should be an opportunity to benefit from the work carried out by others to facilitate building the baseline version of DECAID in the foreseeable future.

All models which are necessary and sufficient for DECAID have not yet been determined. A continuing assessment of which model and data bases are appropriate may eventually provide a complete "suite" of DECAID models. However, it may turn out that if criteria are particularly stringent, no suitable model exists to fill a critical gap, and must therefore be created. It may also turn out that a model is needed which does exist, but for which no supporting data base has been established. It may also happen that models and data bases exist but need to be improved or added to. A great model and data base may exist, but perhaps for a task or situation which is not perceived to be worthy of tactical training. Future tactical requirements and CBR weapon characteristics may dictate that additional models be developed. These are among the challenges to identifying the "suite" of DECAID models and data bases.

Table 9-2

Examples of Potentially Useful Models and their Associated Topics for DECAID.

Category	Topic	Model	Reference
SOURCE	Deposition & Weathering	DAWN	Guess, Wallace, Yencha, and Overman (1988)
	Atmospheric Transport & Diffusion of Chemical Agent	NUSSE	Replogle and Porter (1985)
	Chemical Attack Descriptions	TSARDOSE	Battelle (1988)
PATH	Ventilation Spread of Contaminaton	VENM	Blacksten (1986)
RECEIVER	Heat Stress	TCORE	Ramirez et al. (1988)
	Task Completion Time	TTMS	Ramirez, Rayle, DaPolito, and Shew (1987)
	Crew efficiency levels	PDGRAM	Claiborne (1979)
	Human Reliability	THERP	Swain and Guttmann (1983)
	Crew attrition	AURA	Klopcic (1985)
Other	Ship Stability	BALLAST	Williams (1986)
	Fire Propagation	COMPACT	McWhirter, et al. (1986)
	Progressive Flooding	COMPACT	"
	Network of Tasks	Micro SAINT	Archer, Drews, Laughery, Dahl, & Hegge (1986).

Model Inputs and Outputs

Each model has unique data requirements and data outputs. The parameters will be defined in a data dictionary so that appropriate model inputs can be selected from operational information entered by the DCA and from data bases stored in DECAID. The file manager function described earlier will provide a temporary data store to increase data throughput and to appropriately channel data to/from models, data bases, and information displays.

Sources of Data

As mentioned above, models will obtain their inputs from and through the file manager. The file manager will consist of data base information, data that is entered by the DCA, and sensor information obtained from scenario data files. In later evolutions, it is possible that instructors will have the ability to provide (or override) model inputs for a subset of the required parameters. Models will also have a defined default profile which will provide baseline inputs for required parameters when "real" data are not available.

The file manager "spreadsheet" is to be embodied as active memory that is used to "hold" the DCA's inputs, inputs from pre-stored data bases, and active models that are using the requested data to develop an equation or series of equations that represent the desired output. Alternatively, it could also be used to perform other simulation oriented preprocessing/processing such as that required for running Monte Carlo-type simulation.

Data Analysis "Spreadsheet" Output (TBD)

The exact format of the sequential file or the display file will be defined by the requirements of the detailed design interface specification.

Graphic Information Output (event overlays) (TBD)

The graphic information output will be defined as a function of the storage/creation capability (i.e., if an optical disc is used, the amount and type of graphical information is significantly impacted). However, it is anticipated that graphical output will include:

- Problem-specific displays (i.e., statistical graphics of predictions)
- Graphical overlays (e.g., routes over ship plates)
- Accompanying text and/or audio (e.g., listing of fittings along a route).

DATA BASES

DECAID will use data base files extensively to store, access, and retrieve pertinent CBR-D data and information in an efficient manner. These data bases are expected to support the following:

- models and simulations which might be included in DECAID;
- DCA decision aiding through retrieval of pertinent information when needed;
- instructional delivery through storage, access, and retrieval of training software;
- scenario presentation through storage, maintenance, and updating of a scenario library; and
- student performance archives, e.g., actuarial records on test results or 'traces' of student decision making behavior during scenarios.

The DECAID requirements to process various information files, to import data from one data file and join it with data from another, and to process output from two or more data files justify the use a data integration and analysis package. Figure 9-10 portrays the array of data bases which will feed information into a data analysis "spreadsheet" which could serve the various functions just mentioned. Data display to the DECAID user would be handled through the DECAID application software interface and the file handling routine software.

Due to the fact that DECAID is still in the conceptual stages of development, it is not possible to definitively list the contents of its

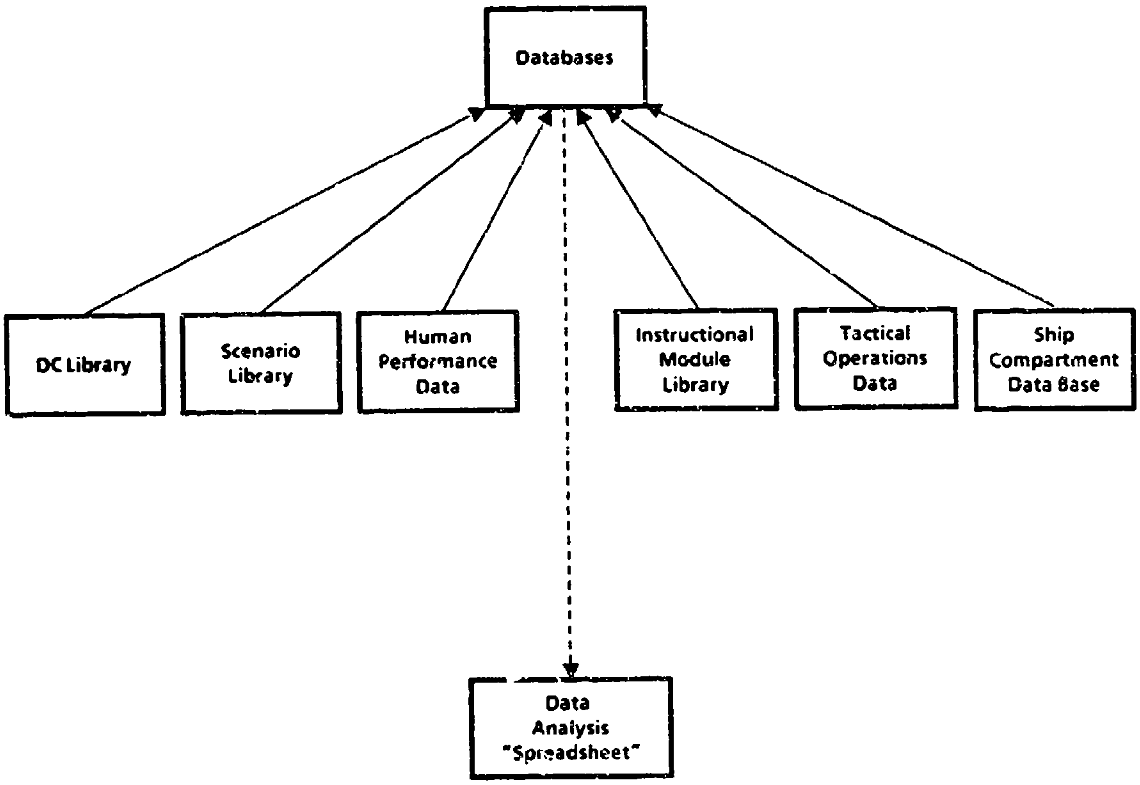

Figure 9-10. Potential DECAID data bases with "spreadsheet" work area.

required data files. However, some categories of data which might eventually find their way into the DECAID data bases is indicated below. More specific information on these data bases will be provided, to the extent possible, in the detailed design specification.

DC Library. One useful data base for the DCA will contain excerpts (if not whole copies) of the standard documentation used aboard ship. As was mentioned earlier, when properly designed, an automated information retrieval system could provide "views" into these documents which are tailored to the situation at hand. What is envisioned is a data base which contains narrative, tabular, and graphic information gathered from such documents as NWP-62-1B, CBR-D Handbook for Training, and NSTM 470, among others. This information would be indexed in such a manner as to afford efficient and effective access and retrieval.

Scenario Library. In Section 6, concepts of use were presented for DECAID scenario presentation to support both schoolhouse training and on-board training (OBT) of the DCA. A scenario library might contain several baseline scenarios which would serve as the building blocks for other scenarios which might be edited and saved for future use. The entries in such a library might include the following:

- Radiological scenario
- Chemical scenario
- Biological Weapons scenario

- Firefighting scenario
- Flooding scenario
- Chemical Attack plus fire scenario

- Chemical Attack plus flooding
- Other

Instructors and students could create variations on baseline scenarios by adding or deleting threats or casualties, changing their onset in a time-ordered event list, their location on the ship, the crew, time, and equipment resources available, and so on. Updates might be shared across ships and with SWOS, thus creating a valuable resource pool for enhancing CBR-D decision making capabilities through practice in a realistic context.

Human Performance Data Base. Data pertinent to human performance could come from a variety of sources. Task analysis data, for instance, might describe the human performance requirements of critical shipboard tasks in terms such as manning, personnel requirements, time and accuracy criteria, and the functional allocation of tasks across time and crew members. A physiological data file might contain information on the fitness of crew members. A cross-training matrix for a particular crew might support scheduling and SUSOPS/CONOPS evaluations.

Instructional Module Library. This data base would contain the various modules used to present material from the DCA course, training on the use of DECAID's decision aids, as well as additional material specifically related to decision making. The exact topics to be included in DECAID's instructional modules are to be determined. However, they may include modules covering such topics as the theory, methods, and decision applications of radiation calculations, principles of ship stability, and chemical warfare agents (types, symptoms, first aid procedures, decontamination procedures), among others.

Tactical Operations Data. It may prove useful to have online access, through DECAID, to data on ship tactical operations. Again, the contents of such a data base have to be determined during the detail design specification. However, some likely tactical operations files might include various ship's bills (e.g., the CBR Bill), as well as doctrines (e.g., the weapons doctrine).

Ship Compartment Data Base. In order to support decision training and aiding, it is useful to have a ship compartment data base. The contents of such a data base must be tailored to the specific models, scenarios, instructional modules, and decision aids included in DECAID; thus, ship compartment data base contents are to be determined during detailed design. However, the following are some of the kinds of information which might be included:

- Compartment Check-Off List (CCOL)
- Compartment volumes
- Ventilation flow rates, vent fittings
- Fire boundaries, fire hazards, fire station
- Flooding boundaries, nearest flood control gear

- Nearest decontamination station
- Electrical power to be secured
- Division which maintains that space at General Quarters (GQ)
- Nearest CBR gear
- Other

Note that some of this information is supported/required by existing systems such as SNIPE and BALLAST.

Data Analysis Spreadsheet. The data analysis spreadsheet is envisioned to provide to types of data. First, there will be individual student profiles which may include individual test results administered through DECAID as well as 'traces' of student decision making behavior within a DECAID scenario. These may be used for evaluation, to suggest remediation which is needed, and to provide the basis for critiques and analyses of individual decision making. Second, there will be actuarial student performance data which is built up over time. These statistics and results might be used for research purposes (e.g., to evaluate decision making between novices and veterans), to guide modifications to the curriculum, to suggest new decision aids, or to indicate a need for additional modules or scenarios.

GRAPHICS

DECAID graphics are critical to scenario realism and training success. Ship plates, for example, define the DCA's structural environment and describe the constraints, hazards, and available tools that impact his decision processes. Bit-mapped color graphics will be used to depict ship structure and to portray fire, flooding, and CBR hazards. Ship compartment information such as flammable/explosive contents, electrical power control points, and ventilation will also be shown through ship-plate graphics and overlays.

As depicted in Figure 9-11, the DECAID graphics package includes the graphics files, a graphics editing package (for making revisions), selected "event" overlays, and a graphics presentation manager (graphics interface shell). DECAID-resident models and data bases will port data to the graphics presentation manager, which will produce graphic information for DECAID users.

Graphics Presentation Manager (Graphics Interface Shell)

The graphics presentation manager serves as an interface between the various models and data bases and interacts with the executive file handling routines to store, format, and present interim data and graphical output as required. This software will be a local subset of the file handling routines and will enable offline and near real time communication between the various data bases and models. If an optical disc is used to store graphics panels or

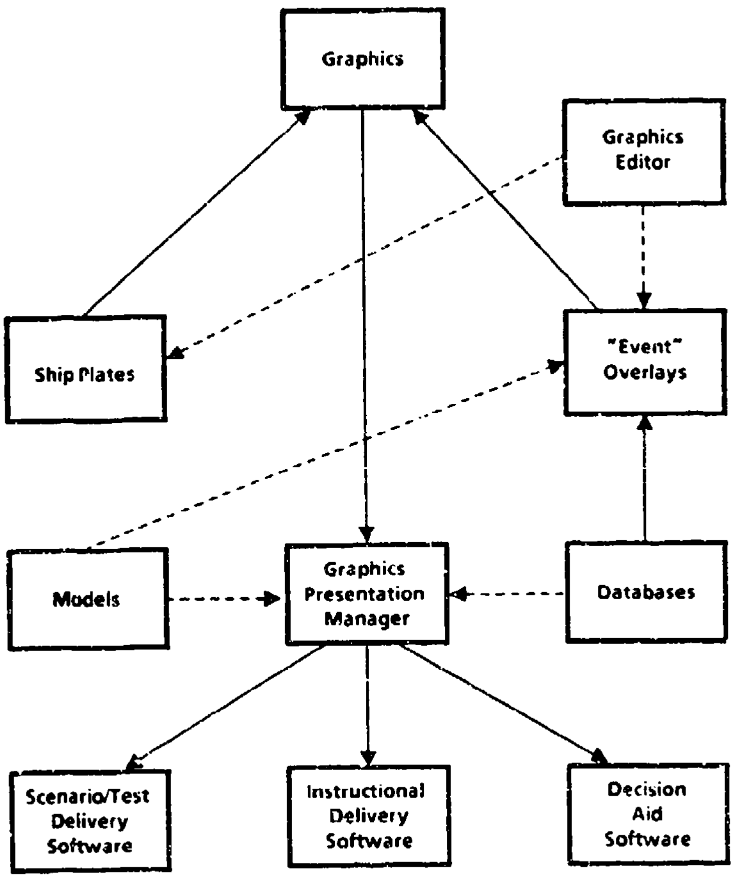

Figure 9-11. Potential DECAID graphics system.

other static visual data, this manager will also integrate the requested output from this device.

Graphics Creation and Editing

Graphics Editor. For OBT or shipboard decision aiding, the graphics editor offers the capability to tailor or modify graphics to specific ships (e.g., ship plates and alterations to their compartments). The graphics editor shall be the principal interface with the user and must control the access to all other functions. These include:

a. Graphics primitives
b. Text creation/modification
c. Editing primitives (copy or cut (delete) character, object, or block; insert/paste; find/replace; undo)
d. File handling (creation, modification, deletion, merging of two files)
e. Input/output control
f. Online help for all functions.

In order to assist the untrained user in the design of displays using the workstation, the user may be able to select icons representing:

a. Various files - these icons shall indicate the type of file, i.e., graphics, text, data bases
b. Input devices which can be selected
c. Output devices on which the output can be displayed.

When the system is booted up, a set of default user input and output devices shall be initialized. Using these devices, the operator shall be given the capability to select other input and output devices or continue to use the default set with no action required by the operator.

User Selectable Library of Graphics Commands. The DECAID workstation user shall be able to access a library of graphics commands directly linked to primitive functions required for creating a new design or modifying an existing design. These commands shall be standard commands such as those in existing graphics systems and include:

a. Common drawing primitives
   - points, lines, circles, rectangles, planar polygons, arcs, polymarkers, polylines

b. Drawing attributes
   - line width, line type (solid/broken), line color, line translucency

- polygon edge style, polygon interior pattern, polygon fill color and translucency

c. Coordinate transformations
   - two dimensional, three dimensional

d. Curve and surface drawing

e. Solids (to the extent possible using the Z-248 hardware capabilities)

f. Hidden surface removal

g. Drawing modification
   - rubber banding, etc.

h. Shading (to the extent possible using the Z-248 hardware capabilities)

i. Color selection and control

j. Windowing
   - size, location, relative location

k. Viewpoint selection and control.

<u>Graphics Creation</u>

- The Input Interpretation Module creates the first level commands and drives the Feedback/Error and Graphic Command Generator modules. This module links the menu item selected with the input device to the software modules related to the selected menu command. The selection of individual ship plates, and other graphic displays from the DECAID data bases, is mechanized through this module as well as the related functions such as dragging an icon, selecting and deselecting a window, etc.

- The Feedback/Error module generates the intermediate feedback to the user by checking for errors, inconsistencies, etc. in user input. Should anything in the input be incorrect, an error message is generated. An error message alone is of no value if the user does not know how to correct the problem. The error detection module will be provided with an associated error correction module. In the limit, the error message will contain sufficient detail such that the user can easily understand the problem and take corrective action.

- The input to the Graphic Command Generator from the Input Interpreter is processed and output to the Display List Generator once sufficient information is obtained to complete a graphics action.

- The Display List Generator provides outputs to the appropriate Display Driver and the Display List Archive of existing graphic files. The display generation software should be independent of the display device as much as possible to allow different implementations to be attempted.

- The Display Driver converts the data to the appropriate format for the selected display and controls the generation of the image on the display device.

- The Display List Archive processes information received from the Display List Generator and provides input to the Display Software Generator.

- The Display Software Generator output is added to a list of previous actions and stored in the software assembly module.

All of the above actions and software activities are coordinated through the graphics presentation manager and becomes part of the application environment when completed.

Linkage of Graphics Privitives to Specific Display Formats. The user of the DECAID system shall be provided a pictorial interface to the relational data base which links specific graphics primitives to specific display formats. Selection of a specific display format shall result in a pictorial display of the hierarchy of graphics primitives used to generate the display format. Most display formats are comprised of objects built up from lower level graphics primitives.

The user shall be provided the capability to shift, rotate, and scale the objects up and down with simple commands. Much of the motion which is to be displayed is parallel motion combined with simple rotation.

Graphics Generation using Model and Data base Output

DECAID shall have the ability to create graphics display files based upon models and data bases.

Graphics Data bases/Data base Management

The user shall have access to the graphical data bases containing the shape data of displayed objects, and movement data base that contains data which describes objects' position and motion.

The data bases shall be organized in an efficient multi-level display list structure. This shall provide the ability to assemble individual components of a geometrical model via multiple modeling transformations, and then display the object using a complete set of viewing operations.

The graphics data base manager shall allow for assignment of various attributes to the different levels in the structure.

The ability to mix graphical and image data on the same display shall be provided. The graphics data base manager shall automatically shift the data to match the view surface definition, allowing the information to be viewed on a set of planes without reformatting by the user. Image data shall be either one-for-one with the pixels to be written, or run-length encoded for compactness. Writing direction shall be under control of the user. Image data shall either replace the pixels already contained on a view surface, or it shall be combined with the original pixels using the Boolean operators AND, OR, or XOR.

CUMULATIVE EXPERIENCE BASE

A long-range option for DECAID is the development of an expert system 'knowledge base' which embodies the cumulative experience of many experts in areas related to damage control and CBR defense. In principle, this knowledge base would represent lessons learned in the real world from areas such as firefighting, flooding control, toxic spill clean up, and disaster preparedness. It might also capture features of novice/student DCA performance.

There are several uses for such a knowledge base in DECAID. The first which comes to mind is for decision aiding by means of an expert system. If embodied in an expert system, this cumulative experience base could help a DCA evaluate a situation more quickly or accurately than if unaided. The expert system could suggest what data to gather, identify unusual or out-of-tolerance data, and offer recommendations on how to counter the threat(s). This is a typical application for knowledge base information.

A second use for a knowledge base might be to tailor instruction itself. As Hayes-Roth, Waterman, and Lenat (1983) explain it, AI instruction systems are intended to diagnose, debug, and shape student behavior. By tracking student performance, such a system would determine weaknesses in the student's knowledge and identify an appropriate remedy. Additionally, the system would plan or put together an instructional module, or sequence of modules, intended to convey the remedial knowledge to the student.

In a previous section, the challenges to developing a knowledge base and expert system were reviewed. It is, however, an enticing goal for long range DECAID improvements and expansion. Therefore, the U.S. Navy may wish to seriously consider the investment in time and effort needed to create such a capability within DECAID.

DCA "TRAINING ADMINISTRATOR"

The DECAID training system will include a DCA "Training Administrator" function that the instructor will use to configure and implement a particular training session. The "Administrator" functions, depicted in Figure 9-12, include test scenario selection and configuration, instructional delivery, scheduling, and recordkeeping functions. One of the important characteristics of the DECAID instructional software is that it will control the decision aiding function. It will limit student access to the decision aid function and will alter the reliability of DECAID to prevent the development of a false sense of security and blind trust in the decision aiding portion of DECAID. Even though DECAID performs calculations and makes suggestions, it is important for the DCA to be able to function effectively aboard ship without DECAID, because initially there will be no decision aid aboard ship. After DECAID is available aboard ship, should a power or equipment failure occur at a critical time, the DCA will need a fall back capability so that he can continue.

DCA "MASTER CHIEF" DECISION SUPPORT SUBFUNCTION

DECAID will provide decision-aiding support to the DCA. As an instructional system, the decision support subfunction will be controllable through training administration software. As shown in Figure 9-13, DECAID will obtain text and graphic information and data from data bases, models, and

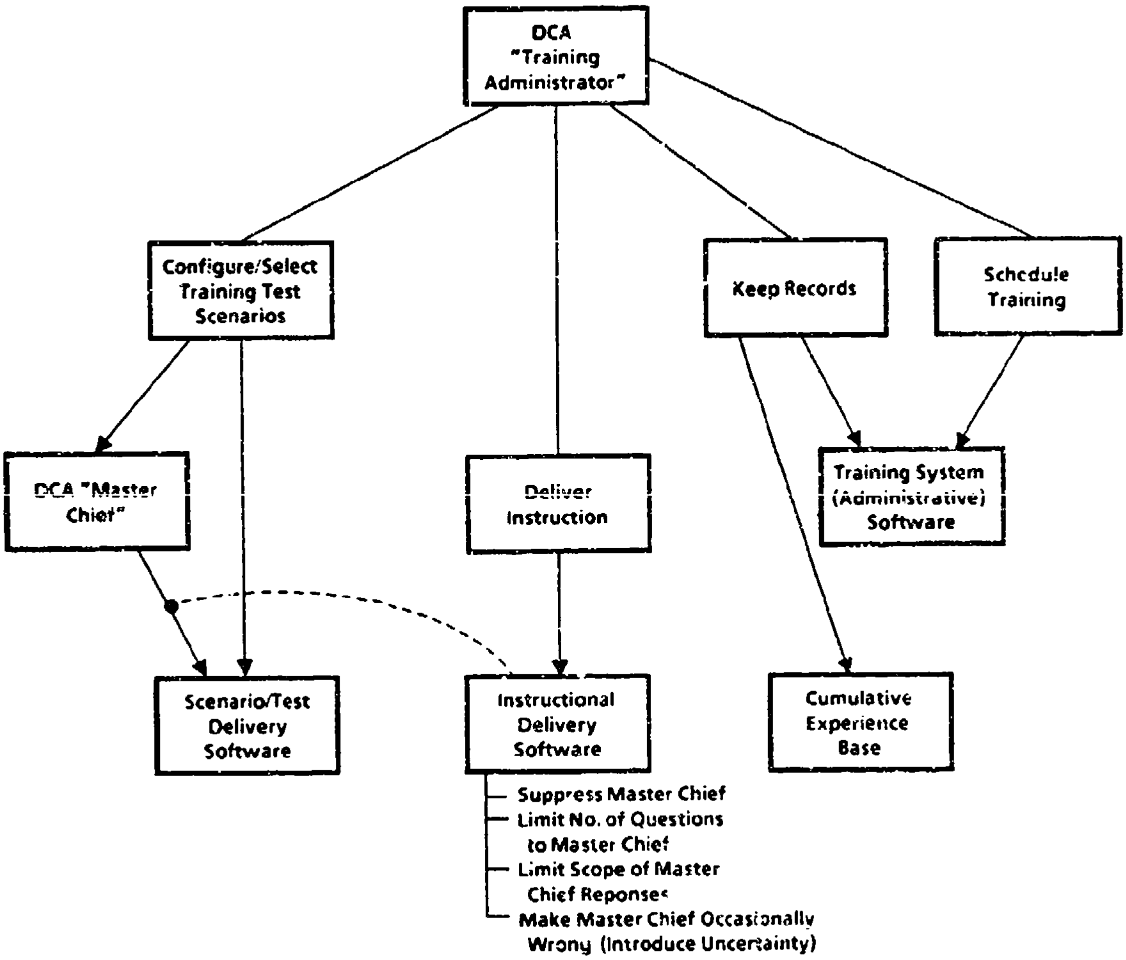

Figure 9-12. DECAID DCA "training administration".

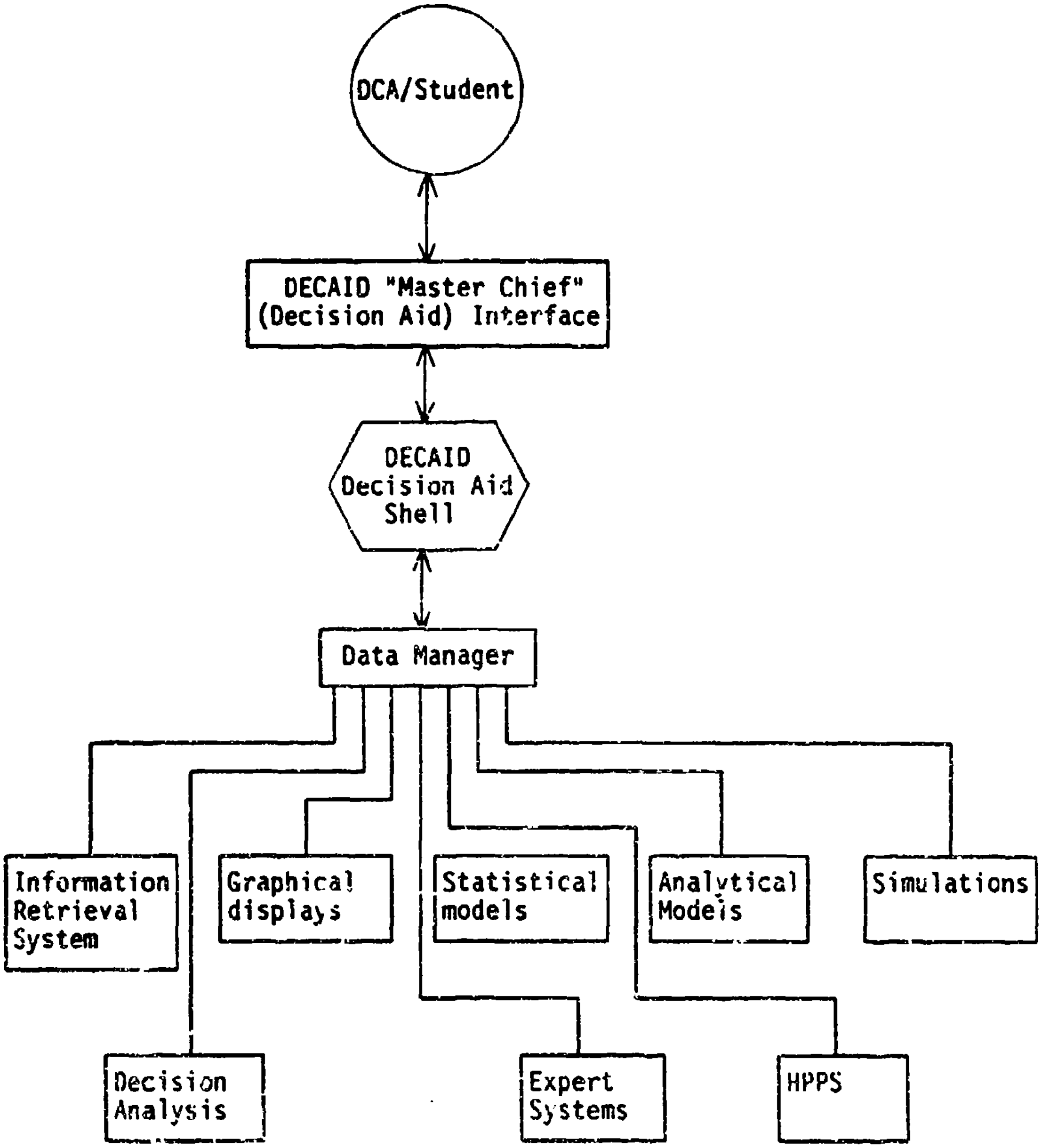

Figure 9-13. DECAID "master chief" decision aiding modules.

simulations for the user. An optional long-range development would be the incorporation of expert or production systems into the decision aiding support subfunction. Such expert systems would be predicated on the development of a body of CBR-D tactical expertise; this could evolve from simulations, war games, and theater training operations. Outcomes selected from the cumulative knowledge base could also be piped through a probability evaluation program (i.e., a Bayesian filter) to assist the DCA in predicting the likelihood of certain outcomes, given certain decisions. It is anticipated that the decision support subfunction would be accessed through the scenario/simulation software user interface.

Master Chief Baseline Definition

The DECAID master chief baseline support subfunction (Figure 9-14) will be configured to support data and information requests from the DCA in order to maximize the DCA's manual problem solving activities that require seeking and obtaining data that needs to be derived from one or more of the models that comprise the DECAID support system. In this mode, the requested data is based on a single query basis (i.e., only one source of data can be requested at a time), and any integration of multiple data sets is a manual task of the DCA -- to the extent it is possible to do so.

In the baseline mode, the master chief is an intermediary processor that accepts requests, initiates a model run based on the DCA's input parameters, and returns the model response data through the creation of a data file on a screen display file. Under this baseline concept, there is no integration, "intelligent" processing, or synthesis of multiple models or data sets. The master chief acts as a clerk to extend the DCA's information seeking capability by accessing existing models and data bases and providing the outputs as data and information. The master chief baseline subfunction is presented in Figure 9-14.

Master Chief Extended Modes (Optional Long-Term Improvement)

As the DECAID system progresses in its development, from the baseline system toward a matured system, the master chief subfunction will also need

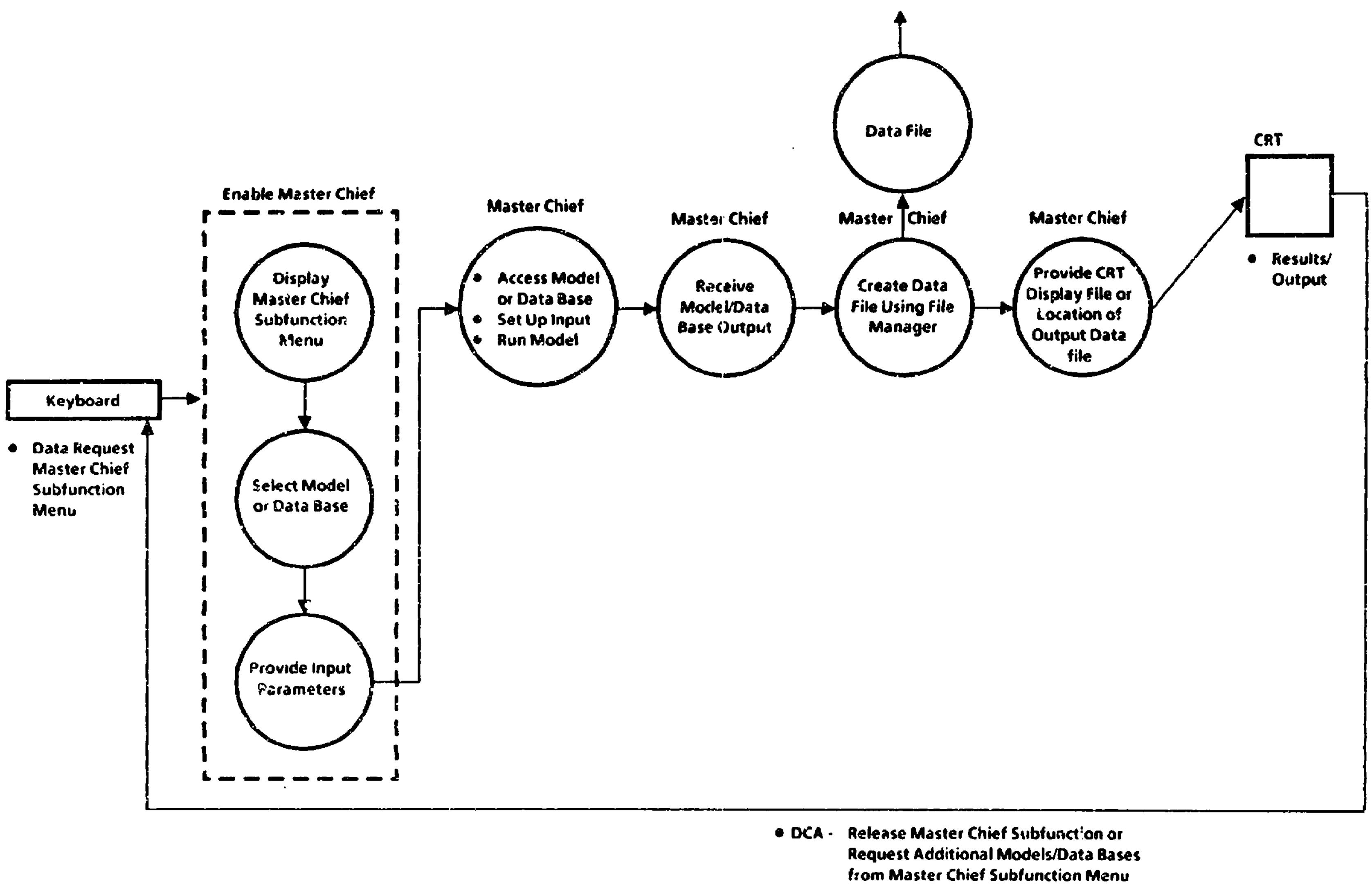

Figure 9-14. Master chief baseline mode subfunction.

to be expanded to other modes of operation. The enhanced "Master Chief" modes will be characterized by increased automatic functions that would eventually include the capability to function continuously in parallel with other ongoing activities and it would also include the capability to seek data and information from multiple sources/channels and integrate/synthesize data and information to provide guidance to the DCA (and others) on complex multi-action activities in response to CBR-D events.

The most advanced concept for the master chief subfunction is embodied as a computer model of the "perfect DCA", and is defined by automated and autonomous functions that act as if the "real" DCA were observing the ongoing dynamics and performing "real time" assessment and decision making. This concept has two (2) distinct states that it can operate in: (a) a normal quiescent state; and (b) an active state that responds to a CBR-D detected event. In the quiescent state (mode quiescent), the master chief performs a continuous online evaluation of ship state based on sensor data, sea states environmental and ecological information and action plan states. This mode can operate independently (assuring a high degree of information and sensor inter-netting), or it can accept DCA inputs. In the active state (mode 2), the master chief, upon detecting a CBR-D event, changes to an "action plan" orientation and begins to seek data and information from the various models and data bases in order to formulate a course (or courses) of action that will stabilize the situation and contain the event to the smallest possible area. In this mode the master chief performs a series of "pattern matching" algorithms geared toward previous behavior in "like" situations, or extrapolates data from past experience and attempts to predict expectations or trends. This ongoing behavior can be modified by direct inputs from the DCA as part of a dialogue. Through iterative ongoing, dialogue, DECAIDS Master Chief would assist the DCA in the development of a plan of action, which when enabled,should respond aggressively to the threat and result in the ship's condition being stabilized with a minimized loss in personnel, material and capability.

Both Mode 1 and Mode 2 are presented conceptually in Figure 9-15.

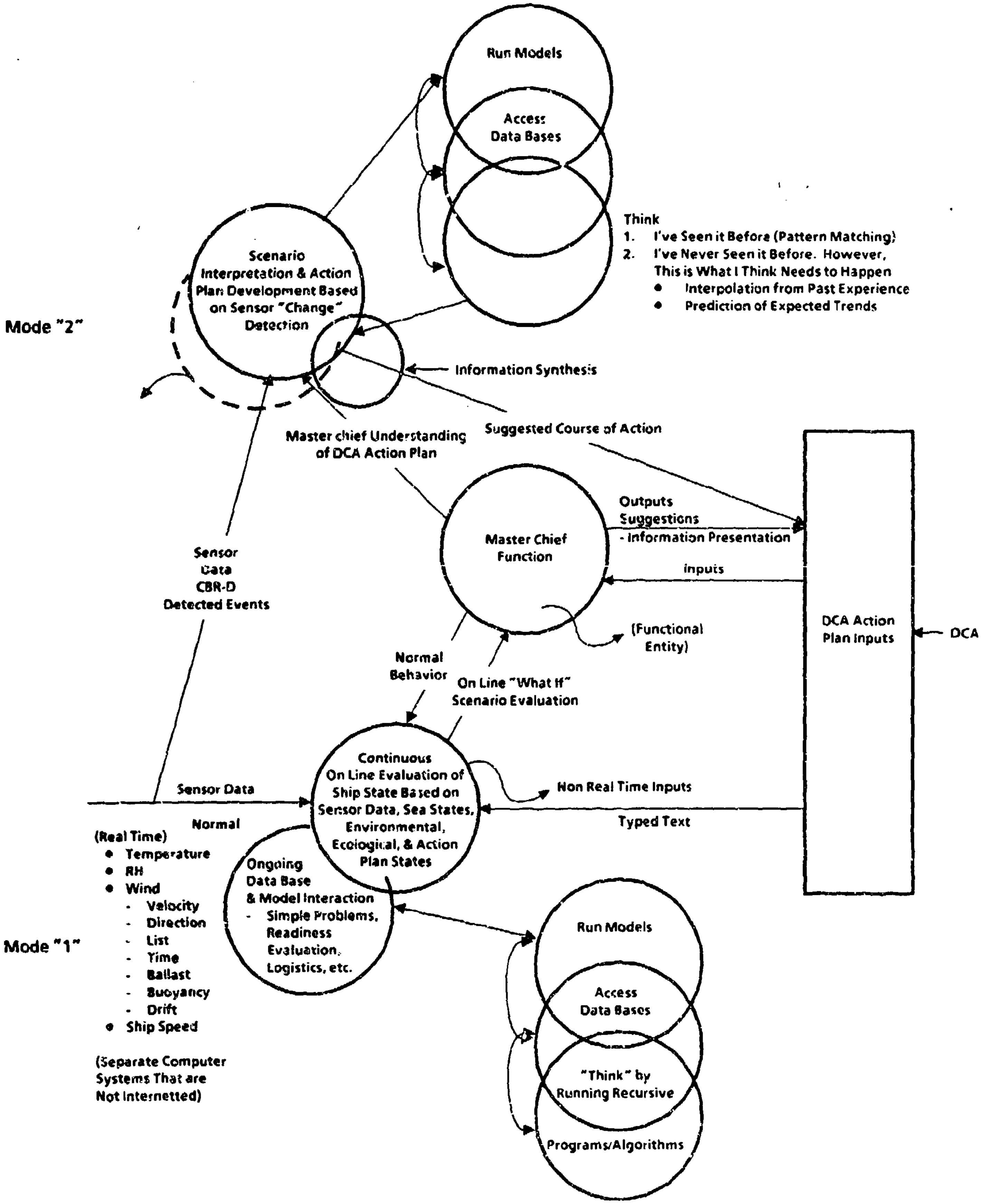

Figure 9-15. Master chief extended modes (optional long-term improvement).

COMPOSITE (SYNTHESIZED) GRAPHIC DISPLAYS

Definition

The ability to provide synthesized data using graphics and multi-sensor fusion algorithms will provide the DCA with a capability to view an array of graphical and textual data in a composite format that provides increased information and suggested courses of action to focus the ongoing situation and to provide a simple view of a dynamic environment. This ability is intended to be "added" to the DECAID as a product improvement option once the basic DECAID structure is established and a historical data base initiated. The definition, design and implementation of the synthesis capability is a complex task which requires a full understanding of the DCA's needs as well as the capability of the current and next generation (1990's) software, and knowledge engineering algorithm development -- and is not a trivial task.

It is envisaged that the data and information synthesis software/graphics will require the speed and complexity of the current and next generation Intel 80386 microprocessor/co-processor type hardware coupled with the state-of-art signal processing electronics and pipelined (geometry engine) graphics processors. The speed and addressing capability represented by these electronic devices/architectures coupled with dynamic knowledge engineering based programming constructs are necessary to the successful fusion/concatenation of diverse sensor/data types which are essential to the composite graphics.

Synthesis Properties Include:

- Simultaneous view of all graphics and tabular data related to the composite graphic.
- Parameter traceability - ability to decompose composite graphic to base elements for validation and assessment.
- Situation awareness - for control and performance activity assessment.
- Secondary threat awareness--
  - multiple event synchronization
  - multiple threat prioritization
  - primary/secondary impact of selected actions/reactions.

- Complex threat interactions--
  - ventilation flow vs. structural damage blockage/re-routing.
- Simulation acceleration of multiple events and impact on ship-deck-compartment.
- Graphical definition capability to categorize, display and respond to synthesized data.
- Animation (graphic over video) image updating.
- Condition/environment degradation/stabilization--
  - Degradation of anti-weapon systems
    - Clothing
    - Agents
    - Retardents
    - Emergency procedures, materials, resources.
- Critical event highlighting
- Data and information insufficiency.

DCA Action Plan Implementation

During the conduct of a scenario run or in the training/instructional mode, the DCA "student" makes a number of decisions, requests the "master chief" to obtain specific data and/or information, and develops and communicates an "action plan" that specifies the sequence of actions that are to take place which will satisfy the scenario. The DECAID system software will be required to capture all of the decisions, requests, data generated and actions in a data/information file which can be accessed by other software which will allow the instructor (or others) to trace (i.e., reconstruct) the activities in the context of the scenario or the training environment.

This software system will exist in the baseline DECAID system as described above. However, as the DECAID design matures, additional software will be required to be implemented which will add additional capability to the master chief subfunction. This additional software, when developed, will be capable of evaluating the DCA inputs in light of the past actions/action plans stored in the lessons learned data base. The resultant output from the master chief subfunction will be in the form of a "feedback" or suggestion algorithm which will provide decision and information in terms of (a) suggestion of things that might be done to improve the action plan; or (b) advice with respect to what other DCA's have proposed in similar situations/scenarios.

INTERFACES

DECAID interfaces include those for hardware, software and data, and system users. The family of DECAID interfaces is shown in Figure 9-16. Each of the interfaces will be discussed in conceptual terms.

Hardware Interfaces

Hardware interfaces are to be defined by the Z-248 device handlers and the selected peripheral devices.

CPU to Printer. This interface would provide hard copy output of information displayed on the screen or in a DECAID data base.

CPU to Other Peripherals. As required by the to-be-developed system definition, this interface would link DECAID to such devices as optional disc, auxiliary memory, large screen displays, or other devices.

CPU to Network (Optional). See previous discussion of networks.

CPU to Keyboard. The Z-248 standard keyboard returns hexadecimal codes (not ASCII) for maximum flexibility. All keys except the control keys (SHIFT, CTRL, ALT) generate both "make" and "break" codes. Thus all keys have a "repeat" built in and continue repeating until released. The keyboard interface consists of a +5 VDC lead, a ground, and two bidirectional signal lines. It is coiled and shielded, and has a 5-wire cable that is permanently attached. The keyboard connects to the CPU backplane with a DIN connector. The keyboard uses an 8049 microcontroller to perform keyboard scan functions.

Software and Data Interfaces

DECAID Software Executive. The operating systems, MS-DOS, XENIX, or OS/2, will be defined by the to-be-developed Detailed Design Specification.

Application Software Integrator (translation software). The translation software works in close cooperation with the system software and its utilities,

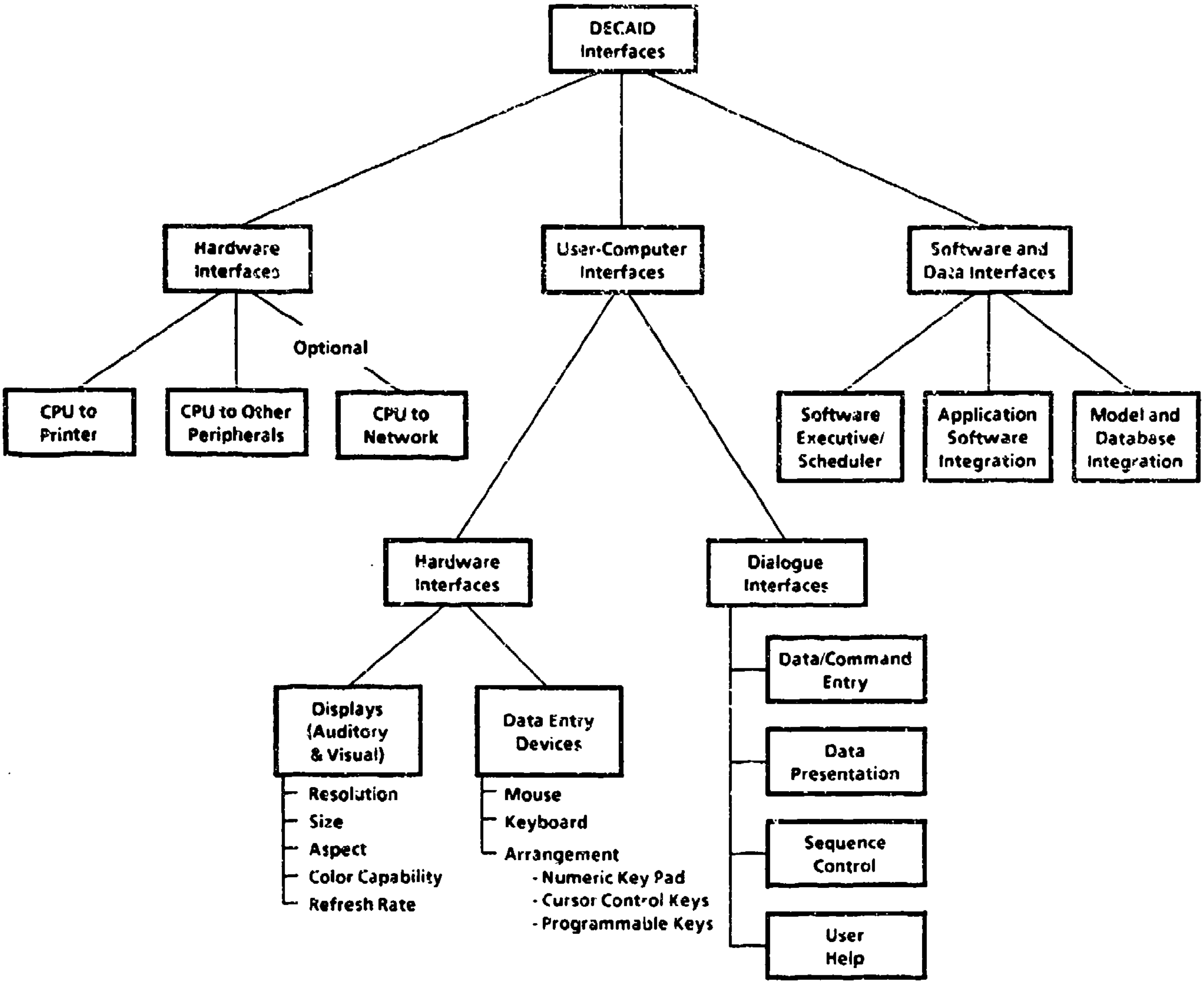

Figure 9-16. DECAID interfaces.

file handling routine software and other DECAID specific software and interacts with the user to provide the application specific environment necessary to exercise the modes and functions of the DECAID system. The specific duties, tasks and activities when defined will cause the DECAID system to perform its intended function by integrating and presenting all of the necessary data and information to the user.

Model and Data base Integrator ("Spreadsheet"). Individual models and data bases must be able to interact with one another, pass data from one to another, and work in concert to generate reasonable outcomes from student decisions that are made during a scenario, to provide optimal recommendations that the student should have used, and so forth. These models must work within to-be-determined constraints of processing speed and memory capacity. They must accommodate expansions and modifications as the need arises. In sum, the models and data bases must be located, selected, evaluated, possibly elaborated, and integrated; then their working effectiveness must be tested, evaluated, and de-bugged as needed.

User-Computer Interfaces

DECAID user-computer interfaces include the user-hardware interfaces (the system input and output channels) and the user-computer dialogue. The user-computer interaction that DECAID supports will be developed in accordance with accepted system design practices. Since the capabilities of DECAID as a training system or decision aid are only accessible to the student DCA through the user-computer interface (UCI), it is important that this interface be designed to promote usability--a goal achieved through attention to the guiding principles of ergonomic design. Williges and Williges (1981, 1984) have identified six fundamentals of interface design. These are:

1. Compatibility - User input should be compatible with computer output and vice versa
2. Consistency - The system should provide a consistent environment to the user and perform in a predictable fashion
3. Brevity - User input and computer output should be brief to minimize user errors and short-term memory loads on the user

4. Flexibility - User input and computer output should depend on user experience, capabilities, expectations, and individual style

5. Immediate Feedback - A human-computer system should be closed loop, with information fed back to the user about system state and user performance

6. Operator Workload - The interface should be designed to keep user workload within acceptable limits.

In order to adhere to these guiding principals, interface development will be directed by appropriate military standards (e.g., MIL-STD-1472C) as well as by the latest design guidelines (e.g., Hamel and Clark, 1986; Smith and Mosier, 1986) and instructional requirements. In addition, user involvement and early testing of prototype interface concepts will be pursued. The following user-computer interface characteristics are anticipated for use in DECAID.

<u>User-Hardware Interfaces</u>. The display portion of the DECAID interface conveys information to the user through visual and auditory means. It also echoes the user's data entry actions to provide feedback that data or commands entered have, in fact, been accepted by the system. The chief DECAID display is anticipated to be its video monitor; a secondary display will be an auditory alarm. The video monitor of preference for full compatibility with the Z-248 is the Zenith color monitor, ZCM-1490. Some of its display attributes are indicated below:

Size:	14-inch, flat technology. Display area 9.84 inches (25.0 cm) wide by 7.09 inches (18.0 cm) high (approximate)
Display Colors:	Infinite array.
Character block:	8 x 19 pixels (Zenith) 9 x 16 " (VGA) 8 x 16 " (MCGA) 8 x 14 " (EGA) 8 x 16 " (CGA, 400-line) 9 x 14 " (MDA) 9 x 14 " (Hercules)
Characters:	80 characters x 25 lines

Resolution:	640 pixels	x 480	lines	(Zenith, VGA)
	640 "	x 480	"	(MCGA)
	320 "	x 200	"	(MCGA)
	640 "	x 350	"	(EGA)
	320 "	x 200	"	(CGA)
	720 "	x 350	"	(MDA)
	720 "	x 350	"	(Hercules)

User controls: Power, brightness, contract, H CENT (Horizontal centering), H SIZE (Horizontal size), V CENT (Vertical centering), and V Size (Vertical Size)

__Hardware data entry interfaces__. It is anticipated that DECAID will make use of several data entry modes. Data entry requirements and feasible device options are listed in Table 9-3; this listing is based on the work of Foley, Wallace, and Chan (1984). Trade-off analyses will be conducted to determine an effective ensemble of data entry devices. It is anticipated that DECAID will require an alphanumeric keyboard and a pointing device such as a mouse, at a minimum. Hardware specifications for the standard keyboard can be found in the "Hardware" portion of this functional description. On the Z-248 standard keyboard, the CAPS LOCK, NUM LOCK, and SCROLL LOCK keys are lit when toggled on, and are unlit when off. The Z-248 also generates an audible click on each key press. Key size, arrangement (including interkey spacing), numeric keypad design, cursor control keys, and programmable function keys adhere to microcomputer standards and user expectations.

__Dialogue Interfaces__

The design of DECAID dialogue also follows system design standards and guidelines. Because the user-computer interface is the only means by which the user can access DECAID's capabilities, it is important that dialogue be as smooth and unencumbered as possible. The system characteristics which make up this dialogue interface are discussed here.

__Data/Command Entry__. Specific data entry syntax and conventions will be developed as appropriate for the devices chosen for the DECAID system and for the dialogue types used in various transactions. Redundant function selection capabilities might include point-and-click activation using the mouse, command entry at the keyboard, and use of predefined keys on the keyboard.

Table 9-3

Data Entry Requirements and Feasible Devices

DATA Entry Requirements	Feasible Devices
Select items, e.g., from a menu of choices	Alphanumeric keyboard Cursor control keys Joystick, absolute Light pen Mouse Programmed function keyboard Soft keys Tablet Tablet with stylus Touch panel Trackball Voice recognizer
Position as cursor to some location	Cursor control keys with auto repeat Joystick, absolute Joystick, velocity controlled Light pen Mouse Tablet Touch panel Trackball Up-down-left-right arrow keys
Sketch, e.g., an area of interest on a graphic display	Dials Joystick, absolute Joystick, velocity controlled Mouse Tablet
Quantify, e.g., enter one or more numbers	Alphanumeric keyboard Joystick, absolute Joystick, velocity controlled Light pen Linear potentiometer Mouse Programmed function keyboard Rotary potentiometer Tablet Tablet with stylus Trackball
Text entry, e.g., explain a decision	Alphanumeric keyboard Light pen Tablet with stylus

Table 9-3 (Continued)

Touch panel
Voice recognizer

Data display. DECAID will attempt to display a facsimile of charts, gauges, alarm panels, etc. that the DCA will have available in DC Central; the major categories of DCA shipboard interfaces to be emulated on DECAID are given in Figure 9-17. Each of these interfaces will be shown via windows. The DCA will have the capability to select different displays from pull-down menus or via icons. Data on the various displays will be updated according to the active instructional module, scenario, or decision aid. Among the shipboard displays which may be represented are:

- DC ship plates.
- Damage Control panel
- Fire and Flooding alarm panel

- Gauges that indicate firemain pressure forward and aft
- Radiation time-intensity plot
- Plot of radiation monitoring stations

Some examples of what the DECAID interface might look like are provided in Figures 9-18 through 9-21. Figure 9-18 shows how a section of the DC plates might be presented to the user. The user might move the cursor about a ship plate and 'click' on a compartment of interest; this would lead to pop-up windows which offer detailed information about that compartment (See Figure 9-19). By selecting from among selections in a pop-up window, specific types of information would be presented (see Figure 9-20). Finally, by activating the appropriate icon, the user could call up a pop-up window of the fire main control system (see Figure 9-21); from such a window, the user could monitor system status or engage the system, e.g., by activating the WWD.

Sequence Control

Sequence control governs the means by which the user may transition from one transaction to another. This implies that sequence control is basically concerned with what designers commonly refer to as the "dialogue" style. A description of the principal dialogue styles is provided below:

Menu - The computer presents a list of options and the user selects one or more of them.

Form-fill - The computer presents a form with blanks and the user fills in these blanks.

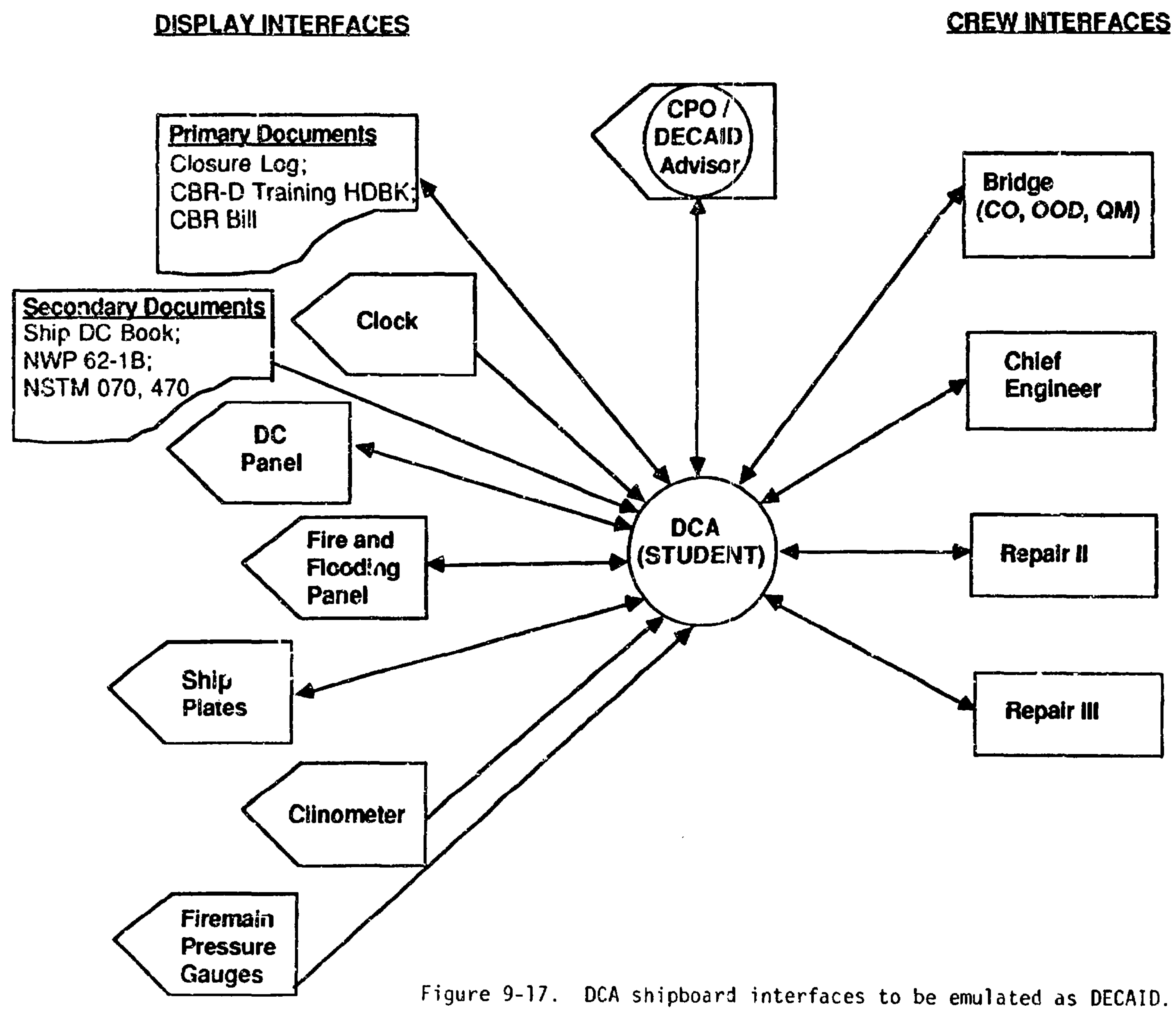

Figure 9-17. DCA shipboard interfaces to be emulated as DECAID.

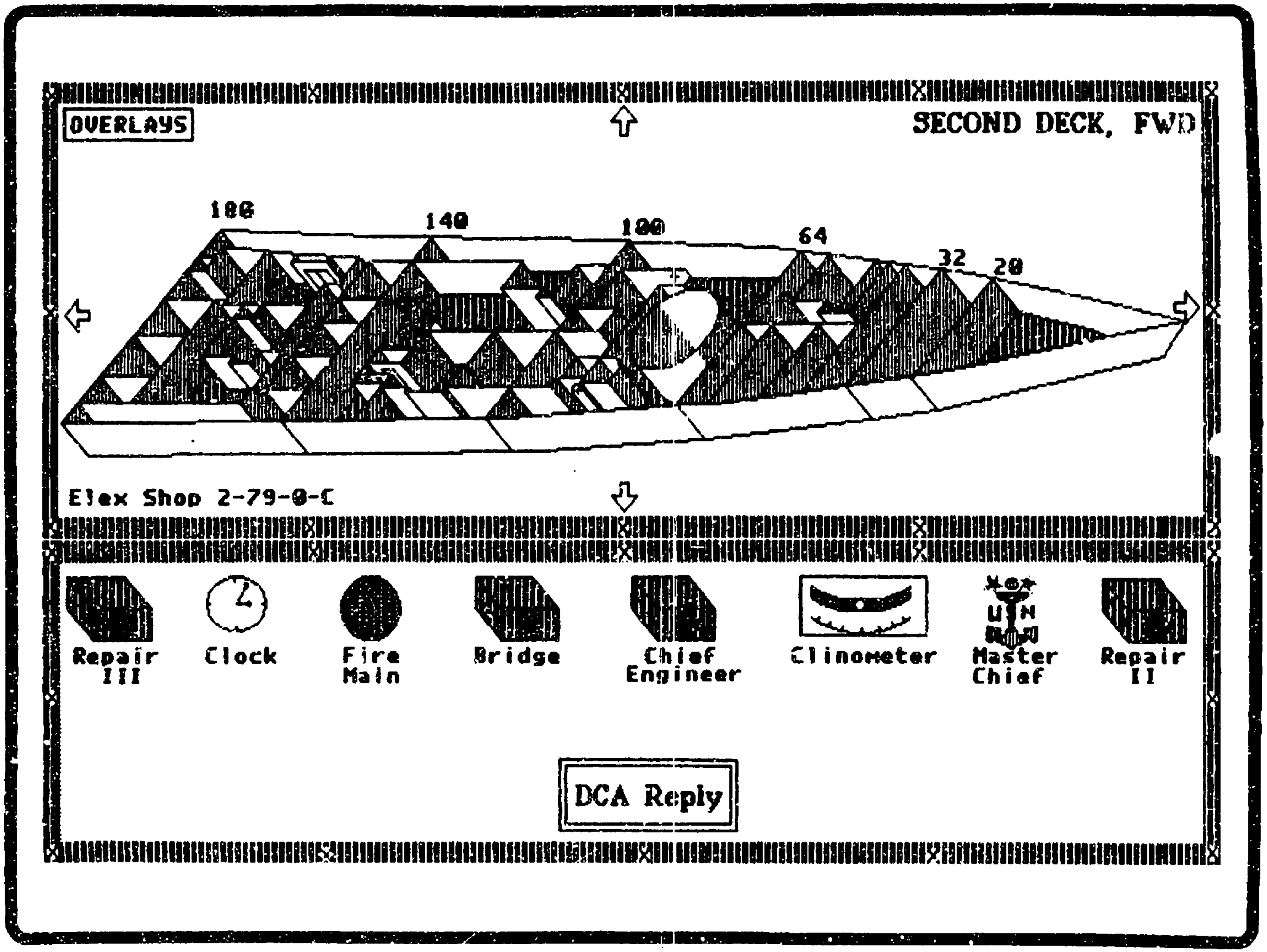

Figure 9-18. Example DCA plate presented through the DECAID interface.

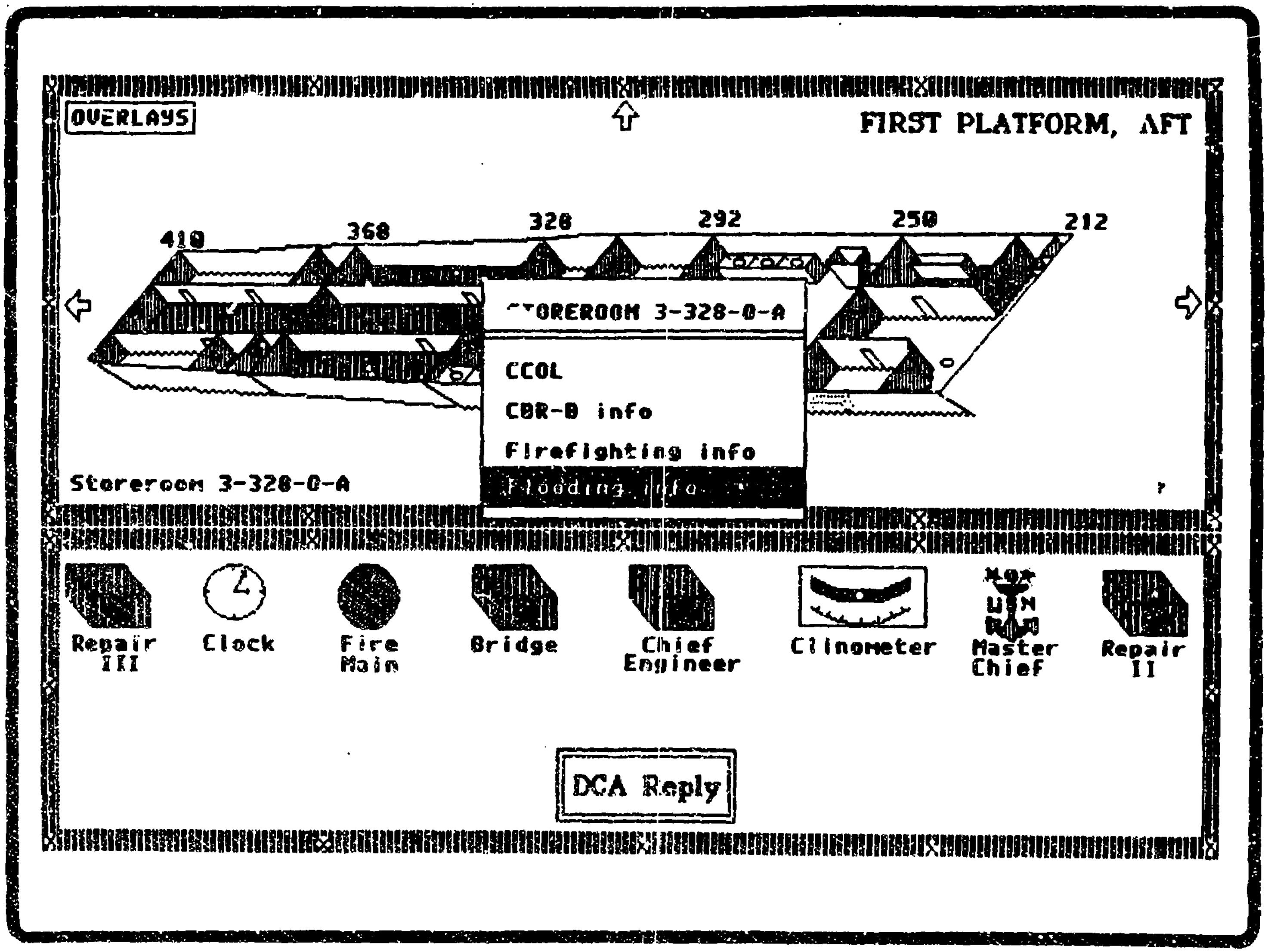

Figure 9-19. Example of a pop-up window related to a particular compartment.

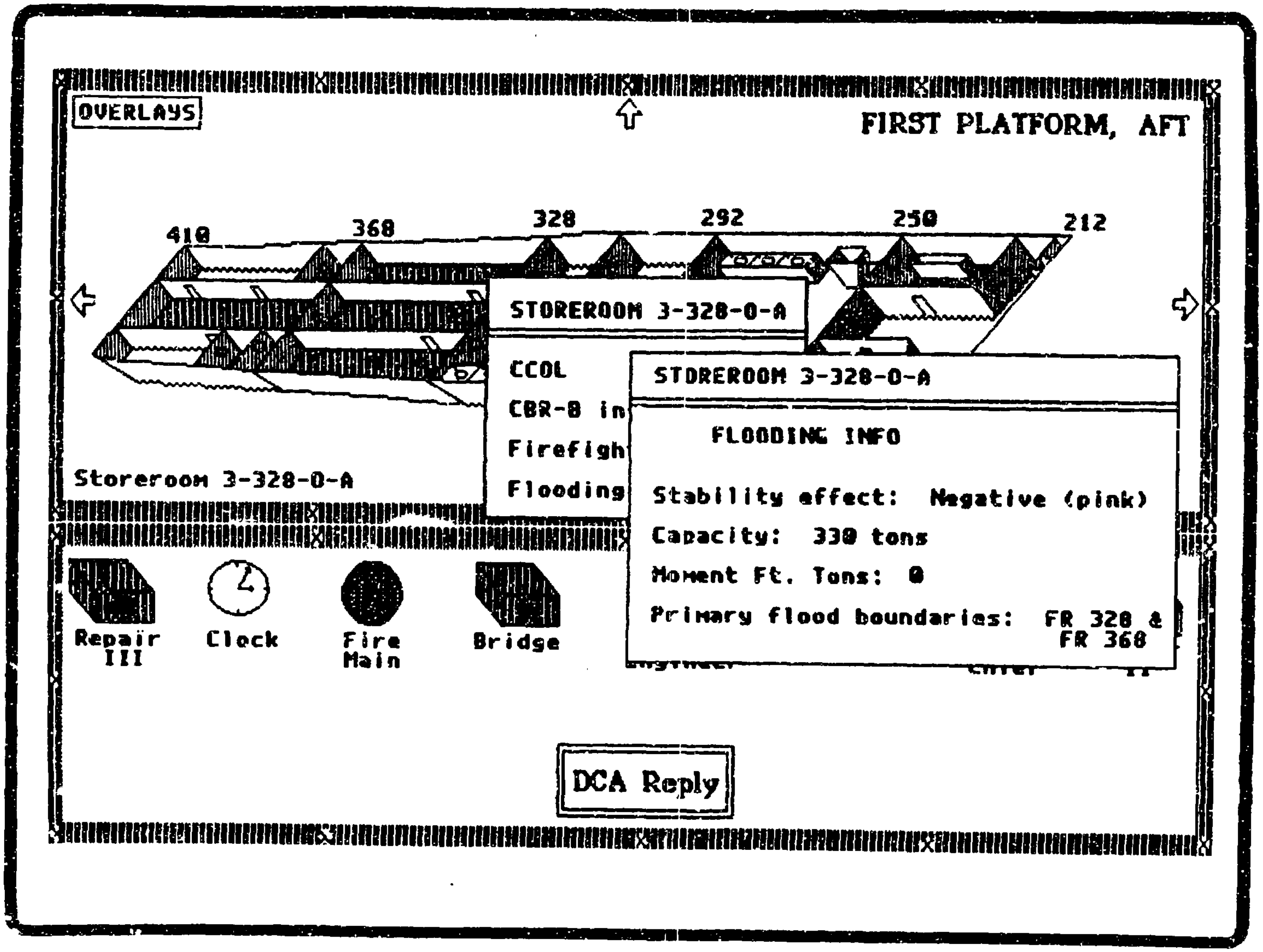

Figure 9-20. Detailed flooding information provided via a pop-up window.

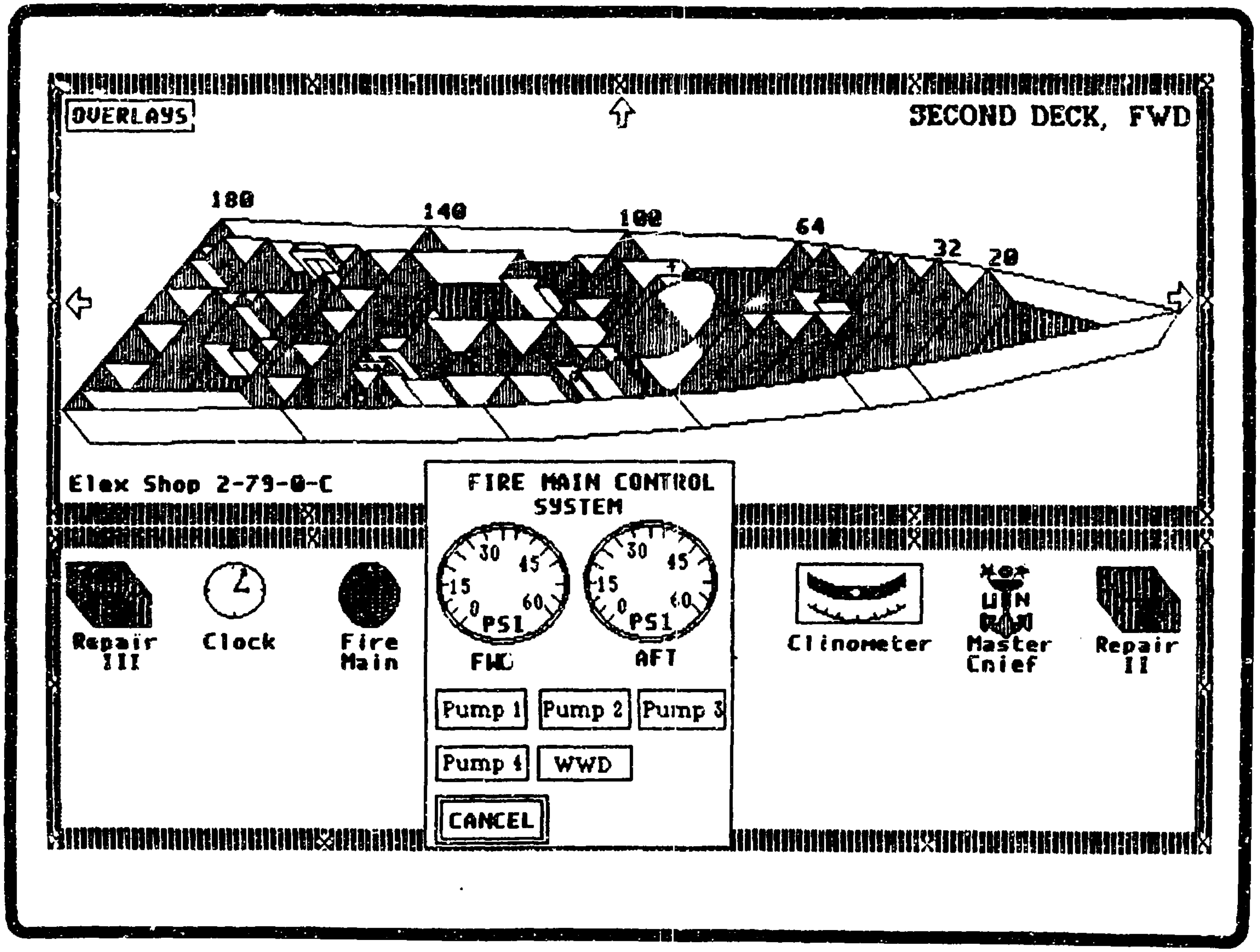

Figure 9-21. Example of a Fire Main control system window called by means of a Fire Main icon.

Function key - The user indicates the desired action/option by depressing keys or soft keys on a video display.

Command language - The user types commands, perhaps using mnemonic abbreviations.

Interactive graphics - This involves the presentation of pictorial displays, the ability of the user to select displayed entities, and spatial locations by pointing or similar nonverbal means.

Question-and-answer - The computer asks a series of questions to which the user responds.

The DECAID interface will probably make use of several different dialogue styles, each of which is best suited to a particular transaction. Menus will provide the system command framework.

User Help

It is anticipated that the DCA instructors and students will require some form of online help to interact successfully with DECAID. Every effort shall be made to promote an error-free interface. However, in those cases where such interface transparency is infeasible or in instances where inadvertent errors arise, user help will be required. This requirement is especially important if the user (student or instructor) will not receive in-depth training on using the DECAID system.

As appropriate, the DECAID Help capabilities will include an appropriate mix of the following:

1. Status information on current data processing
2. Routine feedback provided to the user as transactions are processed
3. Error feedback if an error or other unexpected event prevents routine processing
4. Context-specific guidance on how to proceed in a transaction
5. User help will be accomplished with appropriate error messages, alarms, prompts, and labels, and online instructional material.

Simulated Intraship Communications. The DCA will have the capability to communicate with Repair II and III, with Main Control, and with the Bridge. These will be represented on the display by icons or labels on the screen. When they have traffic for the DCA, they will flash until he selects that station and reads the message (see Figure 9-22). The DCA can communicate to each of the other stations by means of text or by responding to a menu of alternative responses. When one of the communications icons has been selected, it will be presented as the topmost overlapping window of the display. When the commanding officer calls with a question or with directions it may cause that message window to automatically be presented and displayed until the DCA responds. Finally, system messages will be presented as needed in a disceivable format (see Figure 9-23).

DCA "Master Chief" Decision Aid Interface. Finally, consider the interface to a source which may be represented by a crew member or a decision aid device. DECAID will incorporate an aiding module, dubbed the "Master Chief" that will provide assistance to the DCA as the scenario progresses. The Master Chief will be represented by an icon on the display that the DCA may select when he/she needs advice or has a task for the Master Chief to perform (see Figure 9-24). The capabilities of the Master Chief will be based, in part, on the occupational standards for a DCCS. Among the functions that can be performed on request are:

1. Look up information in various documents, such as NWP 62-1, NAVSHIPS TECH MANUAL, NAVSEA CBR-D Handbook for Training, etc. Maintain the DC Closure Log, and provide information on request. Perform stability calculations on request, based on damage sustained.
2. Conduct an inventory of damage control equipage, including CBR-D consumables.
3. Perform radiological calculations, including safe stay time.
4. Calculate recommended watch length and rest periods using heat stress models (or other means).

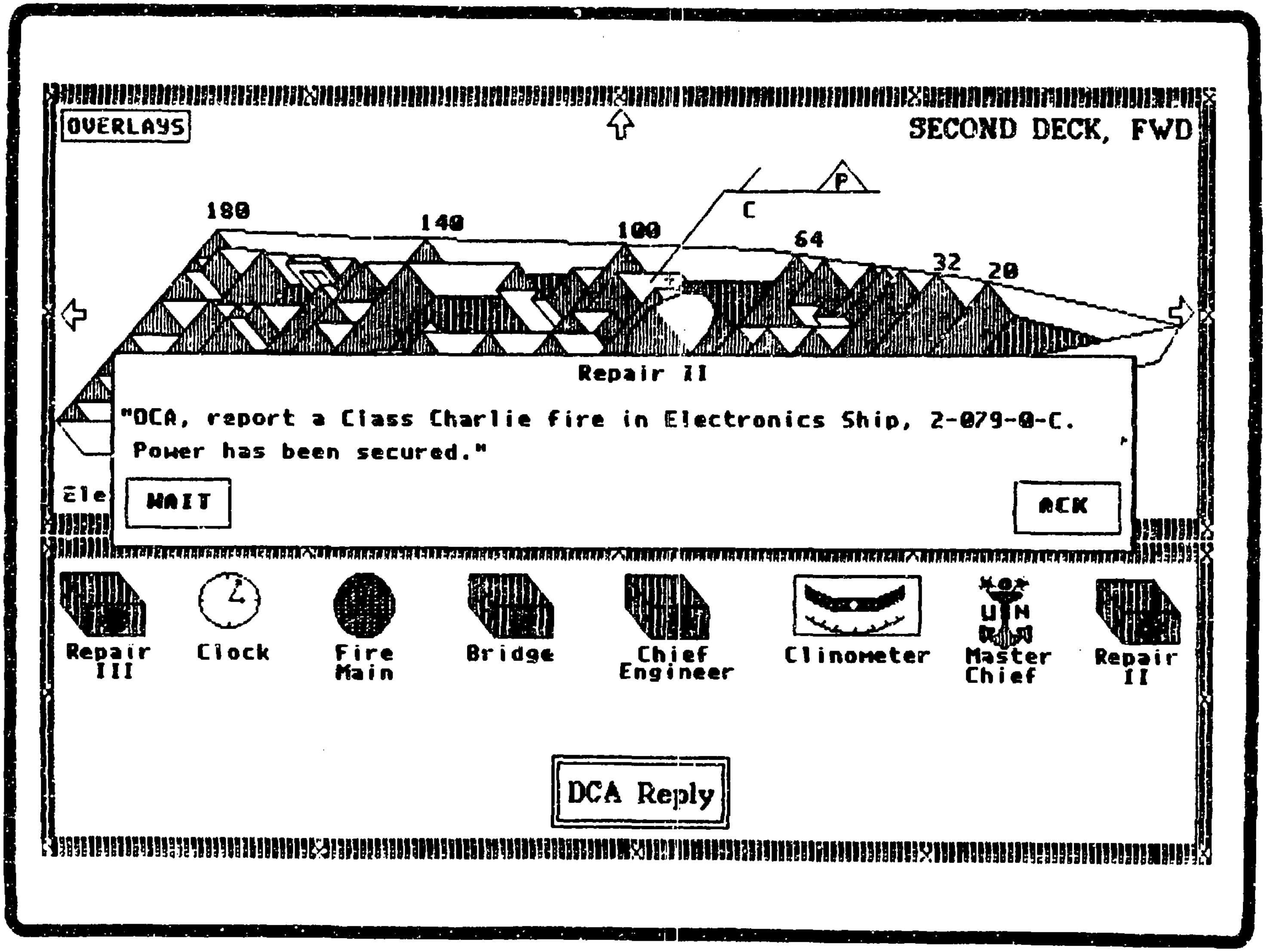

Figure 9-22. Example of intraship communications (Repair II).

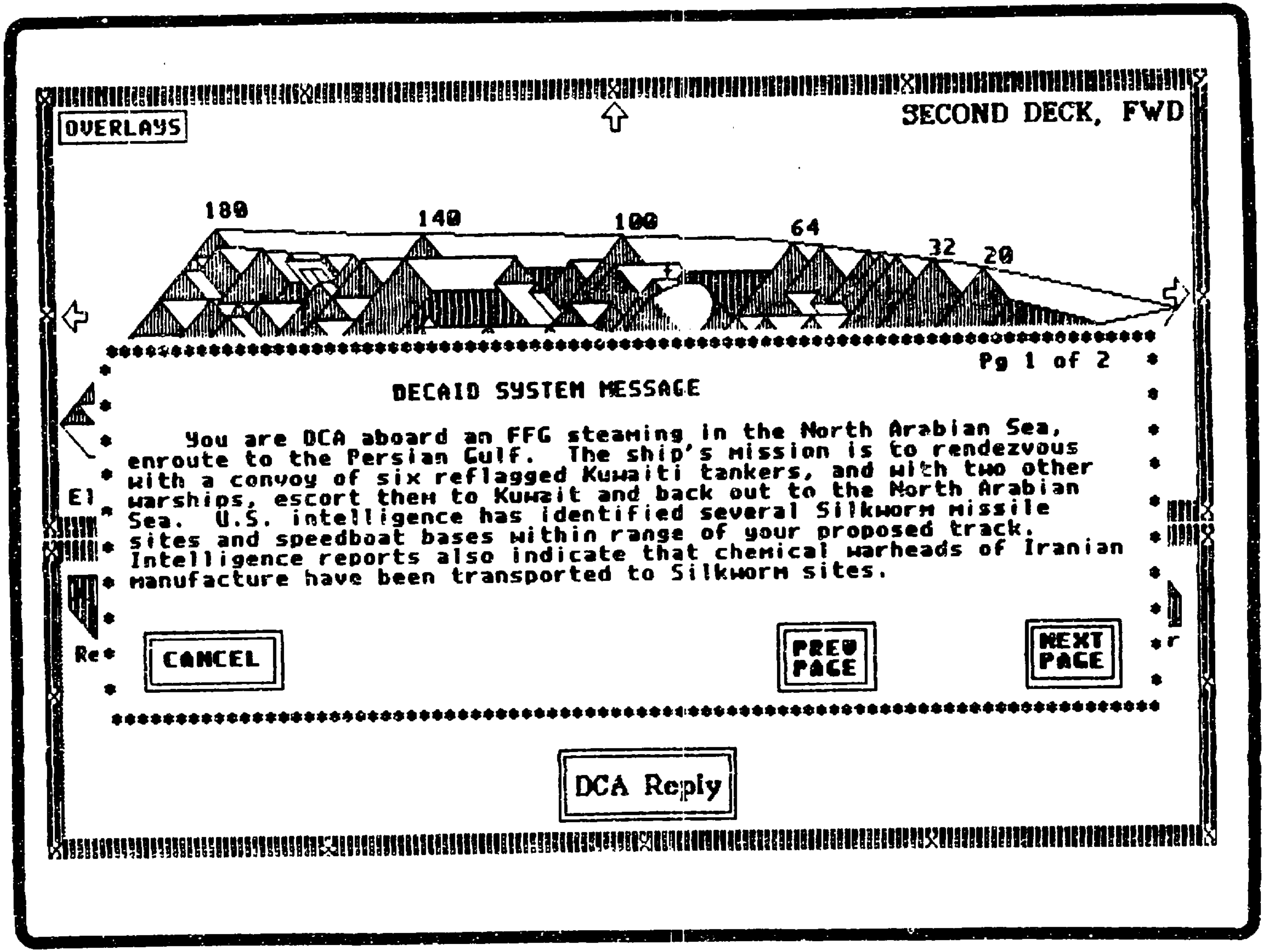

Figure 9-23. Example of DECAID System message.

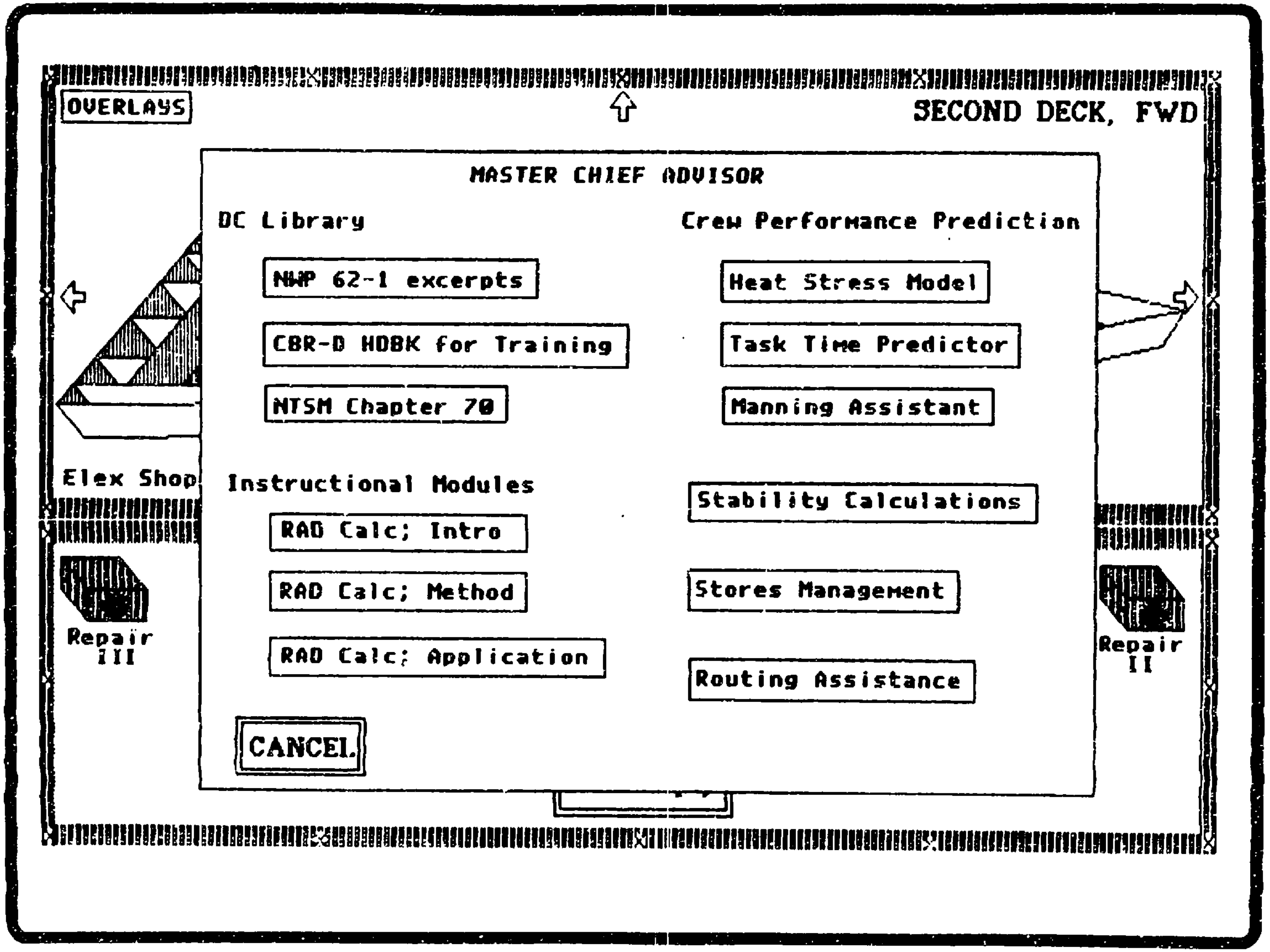

Figure 9-24. DECAID master chief advisory menu.

SECTION 10
SUMMARY

This report, prepared under the sponsorship of the U.S. Naval Training Systems Center (NTSC), has covered several aspects related to improving shipboard decision making in the CBR-D environment. First, a need assessment for decision training in the CBR-D environment was presented. Second, a preliminary analysis of the users and decision tasks associated with shipboard CBR defense was prepared. Third, various concepts of use have been presented under the categories of instructional delivery, scenario presentation, and decision aiding for a conceptual desktop decision aid/training system nicknamed DECAID. Fourth, we have prepared a functional description of a hardware/software system based on Zenith Z-248 technology which may support the concepts of use discussed. Our focus of training and aiding throughout this report has been the surface fleet Damage Control Assistant (DCA).

One may ask why we have focused on decision training and aiding for the DCA. In this regard, we wish to reiterate that, currently, the DCA is the CBR-D officer aboard surface ships. In addition, the DCA is often a junior officer in terms of age, shipboard experience, and administrative decision making experience. Despite these limitations, the DCA is expected to carry out assigned duties with confidence and skill. In both CBR-D and conventional damage control situations, the DCA must orchestrate crew, time, and equipment resources in order to "fix" the ship and protect the crew. The extent to which the DCA serves as an effective decision maker can impact the lives of hundreds of fellow crew members and the safeguard of millions of dollars of Navy materiel. Therefore, we are ardent in our conviction that the DCA focus for DECAID is correct from several vantage points.

Decision training has been a neglected area of instruction and applied psychology. This makes it an admittedly difficult area within which to work. We are not naive in underestimating the challenges surrounding the development of a decision aid/training system such as DECAID. Nor do we hold that the concepts of use included in this report 'say it all' or provide conclusive answers to the implementation of questions and issues which surround decision making. But, we hold that decision training is too important to the effectiveness of naval officers for us not to begin building DECAID and developing its capabilities.

We are certainly not the first to have addressed the issue of decision training and its implementation. In a report prepared approximately a decade ago for NTSC, Nickerson and Feehrer (1975) came to the following conclusions, with which we concur:

> " A training system for decision makers that has a reasonable degree of generality is bound to be a relatively complex system. Moreover, given the current level of understanding of decision processes, it is unlikely that anyone would be able to design a system that would be certain to be satisfactory. The approach that seems most reasonable to us is an explicitly evolutionary one, and one that involves potential users of the system in its development from the earliest stages. What one needs to do is build a working system that represents one's best guess concerning what capabilities such a system should have, and then elaborate, extend, and improve the system in accordance with the insights that are gained through attempts to make use of it." (p. 169).

This report contains our "best guess" as to what DECAID could contain. We have tried to explain our reasoning behind the concepts presented. We have described the functional attributes which a suitable hardware/software system should possess to support DECAID as a desktop system. Now it remains with the Navy to decide on what concepts of use should be implemented and the order in which they should be pursued.

EXECUTIVE SUMMARY

PROBLEM

Chemical, Biological, and Radiological Defense (CBR-D) training has been deficient where it has been dealt with as an independent topic, not related to the overall tactical mission which may be taking place in the CBR environment. The CBR-D area is unique in that the defensive measures (i.e. closing up the ship and outfitting the crew in protective clothing) cause nearly as much mission degradation as would an attack itself. Shipboard decision makers need training to effectively weigh the risks associated with employing CBR defense measures, to make appropriate choices consistent with ship mission, and to plan operations in a CBR-D environment not as an "either...or" situation, but as "both...and", with CBR-D as an additional constraint overlaid on an ship's existing operational tasking.

OBJECTIVE

The objective of this effort is to provide concepts of use and a functional design description for a training device/decision aid (DECAID) that will provide a prospective Damage Control Assistant (DCA) with effective training in shipboard CBR-D decision making.

APPROACH

The approach has been to describe a desktop computer system which would emulate the displays, inputs, and information resources that would be available aboard ship. By means of scenario-driven situations, the DCA would be called upon to make decisions both of a simple, procedural nature and more complex decisions that require risk analysis to determine costs and benefits of the various possible decision options. A decision aid feature dubbed the "master chief" will alert the DCA to risk situations, forecast outcomes based on present conditions, and manage a resource library to assist the DCA in making decisions under conditions of uncertainty.

Several areas of utilization are described: 1. A classroom trainer suitable for use in the Navy's DCA curriculum. 2. A shipboard onboard training (OBT) package for incumbent DCA's to maintain or extend their skills in CBR-D decision making. 3. As a fully operational decision aid, compatible with a Damage Control Management System (DCMS), that would enhance a ship's capabilities to perform it's mission in a real-world CBR-D environment.

CONCLUSIONS

Development of a CBR-D decision aid/training device (DECAID) is feasible through an application of existing technologies. With only minor hardware upgrades it can be installed on the Navy standard (Zenith 248) desktop computer.

Providing DECAID for use in the DCA curriculum and aboard ship for use by incumbent DCA's will correct a longstanding deficiency in CBR-D training.

DECAID displays and communication protocols can be used as the basis for training in other areas of damage control decision making, and might be adapted for use as part of the DC central terminal for a future DCMS.

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